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Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems

A User's Guide

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INVESTIGATION OF INAPPROPRIATE POLLUTANT ENTRIES INTO STORM DRAINAGE SYSTEMS

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NOTICE

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensive engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The purpose of this User's Guide is to provide guidance to municipalities for investigating non-stormwater entries into storm drainage systems. Contaminated non-stormwater entries into storm drainage systems have been shown to contribute substantial levels of contaminants to the Nation's waterways. These entries may originate from many diverse sources including sanitary wastewaters from leaky or directly connected sanitary sewerage and from poorly operating septic tank systems, washwaters from laundries and vehicle service facilities, and many types of industrial wastewaters that are discharged to floor drains leading to the storm drainage or from direct industrial wastewater connections to the storm drainage system. Conventional pollution control programs may be ineffective if these pollutant sources are not identified and corrected.

This User's Guide will be useful to municipalities in conducting required studies as part of their stormwater discharge permit activities, in addition to other interested users. It will enable users to identify the type and to estimate the magnitude of non-stormwater pollutant entries into storm drainage systems and to design needed pollution control activities. An associated demonstration project (Pitt and Lalor publication pending) describes the development and testing of the procedures presented in this User's Guide.

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ABSTRACT

This User's Guide is the result of a series of EPA sponsored research tasks to develop a procedure to investigate non-stormwater entries into storm drainage systems. A number of past projects have found that dry-weather flows discharging from storm drainage systems can contribute significant pollutant loadings to receiving waters. If these loadings are ignored (e.g., by only considering wet-weather stormwater runoff), little improvement in receiving water conditions may occur with many stormwater control programs. These dry-weather flows may originate from many sources, the most important sources may include sanitary wastewater or industrial and commercial pollutant entries, failing septic tank systems, and vehicle maintenance activities. After identification of the outfalls that contain polluted dry-weather flows, additional survey activities are needed to locate and correct the non-stormwater entries into the storm drainage systems.

This User's Guide contains information to allow the design and conduct of local investigations to identify the types and to estimate the magnitudes of these non-stormwater entries.

This report was submitted in partial fulfillment of contracts numbered 68-03-3255 and 68-C9-0033 and cooperative agreement CR-816862 under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1, 1990 to September 30, 1992, and work was completed as of September 30, 1992. This report was prepared under subcontract to Foster-Wheeler Enviresponse, Inc. of Edison, New Jersey, and the Urban Waste Management and Research Center of the University of New Orleans.

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ACKNOWLEDGMENT

This User's Guide contains information that has been developed and tested in a number of separate research reports investigating inappropriate pollutant entries into storm drainage systems. Many case studies were reviewed during early parts of this research to identify the most appropriate methods of investigation. Information that was obtained from these cities is gratefully acknowledged.

Valuable technical assistance concerning industrial dry-weather discharges was provided by Mark Miller and Tom Meinholtz (Triad Engineering, Inc.) who were supported by Kevin Weiss of the NPDES Branch, Permits Division, Office of Water, of the EPA through the Cadmus Group, Inc. Early report guidance was also provided by Gene Driscoll (Woodward Clyde Consultants), also supported by the Permits Division, Office of Water, of the EPA. Dan Murray, of the Center of Environmental Research Information, Cincinnati, Ohio, EPA, also provided support for the publication of this Guide.

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SECTION 1

INTRODUCTION

Current interest in illicit or inappropriate connections to storm drainage systems is an outgrowth of investigations into the larger problem of determining the role urban stormwater runoff plays as a contributor to receiving water quality problems. Urban stormwater runoff is traditionally defined as that portion of precipitation which drains from city surfaces exposed to precipitation and flows via natural or man-made drainage systems into receiving waters. An urban stormwater drainage system also conveys waters and wastes from many other sources. For example, Montoya (1987) found that slightly less than half the water discharged from Sacramento's stormwater drainage system was not directly attributable to precipitation. Sources of some of this water can be identified and accounted for by examining current NPDES (National Pollutant Discharge Elimination System) permit records, for permitted industrial wastewaters that can be discharged to the storm drainage system. However, most of the water comes from other sources, including illicit and/or inappropriate entries to the storm drainage system. These entries can account for a significant amount of the pollutants discharged from storm drainage systems (Pitt and McLean 1986).

The U. S. Environmental Protection Agency's (EPA's) Office of Research and Development's Storm and Combined Sewer Pollution Control Program and the Office of Water's NPDES Program Branch have supported the development of this User's Guide for the investigation of inappropriate entries to storm drainage systems. This User's Guide is designed to provide information and guidance to local agencies by meeting the following objectives of:

1. Identifying and describing the most significant pronounced sources of non-stormwater pollutant entries into storm drainage systems.

2. Describing an investigative procedure that will allow for the determination of whether significant non-stormwater entries are present in a storm drainage system, and then to identify the particular source, as an aid to the ultimate location of the source.

The background study prepared in conjunction with this User's Guide (Pitt and Lalor publication pending) examined three categories of non-stormwater outfall discharges: pathogenic/toxicant, nuisance and aquatic life threatening, and clean water. The most important category is outfall discharges containing pathogenic or toxic pollutants. The most likely sources for this category are sanitary or industrial wastewaters. The outfall analysis procedure described in this User's Guide has a high probability of identifying all of the outfalls in this most critical category. High probabilities of detection of other contaminated outfalls are also likely when using these procedures. After identification of the contaminated outfalls, their associated drainage areas are then subjected to a detailed source identification investigation. The identified pollutant sources are then corrected.

ROLE OF DRY-WEATHER FLOWS IN URBAN STORMWATER RUNOFF ANALYSES

The EPA's Nationwide Urban Runoff Program (NURP) highlighted the significance of pollutants from illicit entries into urban storm drainage (EPA 1983). Such entries may be evidenced by flow from storm drain outfalls following and during substantial dry periods. Such flow, frequently referred to as "baseflow" or "dry-weather flow", could be the result of direct "illicit connections" as mentioned in the NURP final report (EPA 1983), or could result from indirect connections (e.g., leaky sanitary sewerage contributions through infiltration). Many of these dry-weather flows are continuous and would therefore also occur during rain induced runoff periods. Pollutant contributions from the dry-weather flows in some storm drains have been shown to be high enough to significantly degrade water quality because of their substantial contributions to the annual mass pollutant loadings to receiving waters.

Dry-weather flows and wet-weather flows have been monitored during several urban runoff studies. These studies have found that discharges observed at outfalls during dry weather were significantly different from wet-weather discharges. Data collected during the 1984 Toronto Area Watershed Management Strategy Study (TAWMSS) monitored and characterized both stormwater and baseflows (Pitt and McLean 1986). This project involved intensive monitoring in two test areas (one a mixed residential and commercial area, and the other an industrial area) during both warm and cold weather and during both wet and dry weather. The annual mass discharges of many pollutants were found to be dominated by dry-weather processes.

During the mid-1980s, several individual municipalities and urban counties initiated studies to identify and correct illicit connections to their storm drain systems. This action was usually taken in response to receiving water quality problems or information noted during individual NURP projects. Data from these studies indicate the magnitude of the cross-connection problem in many urban areas. From 1984 to 1986, Washtenaw County, Michigan dye-tested 160 businesses in an effort to locate direct illicit connections to the County stormwater drainage. Of the businesses tested, 61 (38 percent) were found to have improper storm drain connections (Schmidt and Spencer 1986). In 1987, the Huron River Pollution Abatement Program dye-tested 1067 commercial, industrial, and tax exempt businesses and buildings. A total of 154 (14 percent) were found to have improper connections to storm drainage (Washtenaw Co. 1988). Commercial car washes and other automobile related businesses were responsible for the majority of the illicit connections in both studies. Discharges from commercial laundries were also noted. An investigation of outfalls from the separate storm drain system in Toronto, Canada revealed 59 percent with dry-weather flows. Of these, 84 (14 percent of the total outfalls) were identified as grossly polluted based on the results of a battery of chemical tests (GLA 1983). In 1987, an inspection of the 90 urban stormwater outfalls draining into Inner Grays Harbor in Washington revealed 29 (32 percent) flowing during dry weather (Pelletier and Determan 1988). A total of 19 outfalls (21 percent) were described as suspect based on visual observation and/or anomalous pollutant levels as compared to those expected in typical urban stormwater runoff characterized by the EPA 1983 NURP report.

CURRENT LEGISLATION

With additional data now available, the Clean Water Act of 1987 contained provisions specifically addressing discharges from storm drainage systems. Section 402 (p) (3) (B) provides that permits for such discharges:

i. May be issued on a system or jurisdiction-wide basis.

ii. Shall include a requirement to effectively prohibit non-stormwater discharges into the storm drains, and

iii. Shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

In response to these provisions, the EPA issued a final rule to begin implementation of section 402(p) of the Clean Water Act on November 16, 1990 (40 CFR parts 122, 123, and 124 National Pollutant Discharge Elimination System Permit Regulations for Storm Water Discharges, Federal Register, Vol. 55, No. 222). A screening approach which includes chemical testing of outfalls or storm drainage with dry-weather flow (defined by a 72-hour antecedent dry period), was adopted. The parameters to be tested are a combination of several pollutants of concern and "tracers" that may be used to help identify contaminated outfalls and predict the source of illicit discharges.

Section 122.26 (d) (1) (iv) (D) of the rule applies specifically to this User's Guide. The EPA requires an initial screening program to provide a means of detecting high levels of pollutants in storm sewerage. The protocol of this User's Guide seeks to determine whether or not non-stormwater flows are causing problems (e.g. pathogenic, toxic, aquatic life threatening, nuisance), and to provide additional detail with respect to the source. It accomplishes this by outlining an effective screening methodology to identify storm drainage system outfalls contaminated by illicit or inappropriate discharges and to determine specifically how the likely sources can be identified. This protocol is supported by a research report (Pitt and Lalor publication pending) containing the results of a demonstration project using these procedures and much more detailed information.

SECTION 2

OVERVIEW

POTENTIAL DRY-WEATHER DISCHARGE SOURCES

This User's Guide is directed to the identification and location of non-stormwater entries into storm drainage systems. It is important to note that for any effective investigation of pollution within a stormwater system, all pollutant sources must be included. Prior research has shown, that for many pollutants, stormwater may contribute the smaller portion of the total pollutant mass discharged from a storm drainage system. Significant pollutant sources may include dry-weather entries occurring during both warm and cold months and snowmelt runoff, in addition to conventional stormwater associated with rainfall. Consequently, much less pollution reduction benefit will occur if only stormwater is considered in a control plan for controlling storm drainage discharges. This User's Guide contains a protocol to identify sources of inappropriate entries to storm drainage systems. The investigations presented in this User's Guide may also identify illicit point source outfalls that do not carry stormwater. Obviously, these outfalls also need to be controlled and permitted.

Table 1 summarizes the potential sources of contaminated entries into storm drainage systems, along with their likely flow characteristics. The following subsections summarize these sources.

Residential and Commercial Sources

The most common potential non-stormwater entries, which have been identified by a review of documented case studies for commercial and residential areas are:

- Sanitary wastewater sources:
  - sanitary wastewater (usually untreated) from improper sewerage connections, exfiltration, or leakage
  - effluent from improperly operating, or improperly designed, nearby septic tanks

- Automobile maintenance and operation sources:
  - car wash wastewaters
  - radiator flushing wastewater
  - engine de-greasing wastes
  - improper oil disposal
  - leaky underground storage tanks

- Irrigation sources:
  - lawn runoff from over-watering
  - direct spraying of impervious surfaces

- Relatively clean sources:
  - infiltrating groundwater
  - water routed from pre-existing springs or streams
  - infiltrating potable water from leaking water mains

TABLE 1. POTENTIAL INAPPROPRIATE ENTRIES INTO STORM DRAINAGE SYSTEMS

Potential Source:	Storm Drain Entry		Flow Characteristics		Contamination Category		
	Direct	Indirect	Conti-nous	Inter-mittent	Patho-genic/ Toxic	Nuis-ance	Clear
Residential Areas:							
Sanitary Wastewater	X	x	X	x	X	x	
Septic tank effluent		X	X	x	X	x	
Household chemicals	x	X		X	X		
Laundry wastewater	X			X		X	
Excess landscaping watering		X		X	x	x	X
Leaking potable water pipes		X	X				X
Commercial Areas:							
Gasoline filling station	X	x		X	X		
Vehicle maintenance/repair	X	x		X	X		
Laundry wastewater	X		X	x	x	X	
Construction site de-watering		X	X	x		X	
Sanitary wastewater	X	x	X		X		
Industrial Areas:							
Leaking tanks and pipes	x	X	X	x	X		
Miscellaneous process waters[1]	X	x	X	x	X	x	x

Note: X: most likely condition
x: may occur
blank: not very likely

[1] see Table 2 for industrial examples

- Other sources:
  - laundry wastewaters
  - non-contact cooling water
  - metal plating baths
  - dewatering of construction sites
  - washing of concrete ready-mix trucks
  - sump pump discharges
  - improper disposal of household toxic substances
  - spills from roadway and other accidents
  - chemical, hazardous materials, garbage, sanitary sludge landfills and disposal sites

From the above list, sanitary wastewater is the most significant source of bacteria and oxygen demanding substances, while automobile maintenance and plating baths are the most significant sources of toxicants. Waste discharges associated with the improper disposal of oil and household toxicants tend to be intermittent and low volume. These wastes may therefore not reach the stormwater outfalls unless carried by higher flows from another source, or by stormwater during rains.

Industrial Sources

There are several types of industrial dry-weather entries to storm drainage systems. Common examples include the discharge of cooling water, rinse water, other process wastewater, and sanitary wastewater. Industrial pollutant sources tend to be related to the raw materials used, final product, and the waste or byproducts created. Guidance on typical discharge characteristics associated with common industries is given in Sections 4, 5, and 6.

There is also a high potential for unauthorized connections within older industries. One reason for this is that at the time of an industry's development, sanitary sewers may not have been in existence, since early storm drains preceded the development of many sanitary sewer systems. Also a lack of accurate maps of sanitary and storm drain lines may lead to confusion as to their proper identification. In addition, when the activities within an industry change or expand, there is a possibility for illicit or inadvertent connections, e.g., floor drains and other storm drain connections receiving industrial discharges which should be treated before disposal. Finally, industries processing large volumes of water may find sanitary sewer flow-carrying capacity inadequate or sanitary sewers located too far away, leading to improper removal of excess water through the storm drain system.

Continuous processes, e.g., industrial manufacturing, are important potential sources because any waste streams produced are likely to be constantly flowing. Detection of dry-weather discharges from these sources is therefore made easier, because the continuous and probably undiluted nature of these discharges is more discernable, e.g., odors produced will be stronger and colors more intense along with their tracer constituents being more concentrated and more readily detected by sampling.

Intermittent Sources

The presence of regular, but intermittent, flows will usually be a good indication of contaminated entries to the storm drains, and can usually be distinguished from groundwater infiltration flows. However, as drainage areas increase in size, many intermittent flows will combine to create a continuous composite flow. Examples of possible situations or activities that can produce intermittent dry-weather flows are:

- Wash-up operations at the end of a work shift, or job activity.
- Wash-down following irregular accidents and spills.
- Disposal of process batches or rinse water baths.

- Over-irrigation of lawns.
- Vehicle maintenance, e.g., washing, radiator flushing, and engine de-greasing.

Industries that operate on a seasonal basis, e.g., fruit canning and tourism can be a source of longer duration intermittent discharges.

Direct Connections to Storm Drains

Direct connections are defined in this Guide as physical connections of sanitary, commercial, or industrial piping (or channels) carrying untreated or partially treated wastewaters to a separate storm drainage system. These connections are usually unauthorized. They may be intentional or may be accidental due to mistaken identification of sanitary sewerlines. They represent the most common source of entries to storm drains by industry.

Direct connections can result in continual or intermittent dry-weather entries of contaminants into the storm drain. Some common situations are:

- Sanitary sewerlines that tie into a storm drain.
- Foundation drains or residential sump-pump discharges that are frequently connected to storm drains. While this practice may be quite appropriate in many cases, it can be a source of contamination when the local groundwater is contaminated, as for example by septic tank failures.
- Commercial laundries and car wash establishments that may route process wastewaters to storm drains rather than sanitary sewers.

Infiltration to Storm Drains

Infiltration into storm drains most commonly occurs through leaking pipe joints and poor connections to catch basins and manhole chimneys but can also be due to other causes, such as damaged pipes and subsidence.

Storm drains, as well as natural drainage channels, can therefore intercept and convey subsurface groundwater and percolating waters. In many cases, these waters will be uncontaminated and have variable flows due to fluctuations in the level of the water table and percolation from rainfall events.

Underground potable water main breaks are another potential clean water source to storm drains. While such occurrences are not a direct pollution source, they should obviously be corrected.

Groundwater may be contaminated, either in localized areas or on a relatively widespread basis. In cases where infiltration into the storm drains occurs, it can be a source of excessive contaminant levels in the storm drains. Potential sources of groundwater contamination include, but are not limited to:

- Failing or nearby septic tank systems.
- Exfiltration from sanitary sewers in poor repair.
- Leaking underground (and above-ground) storage tanks (LUST) and pipes.
- Landfill seepage.
- Hazardous waste disposal sites.
- Naturally occurring toxicants and pollutants due to surrounding geological or natural environment.

Leaks from underground and above-ground storage tanks and pipes are a common source of soil and groundwater pollution and may lead to continuously contaminated dry-weather entries. These situations are usually found in commercial operations such as gasoline service stations, or industries involving the piped transfer of process liquids over long distances and the storage of large quantities of fuel, e.g., petroleum refineries.

INVESTIGATION METHODOLOGY

Applying the methodology presented in this User's Guide will determine if a storm drain outfall (and drainage system) is affected by pronounced non-stormwater entries. In many cases, the information to be collected by using this methodology will also result in a description of the most likely sources of these discharges.

Several aspects of this methodology were derived from the experience of many municipalities that have previously investigated inappropriate entries into storm drainage systems.

The methodology establishes priorities to identify the areas with the highest potential for causing problems. The investigative procedures then separate the storm drain outfalls into three general categories (with a known level of confidence) to identify which outfalls (and drainage areas) need further analyses and investigations. These categories are outfalls affected by non-stormwater entries from: (1) pathogenic or toxic pollutant sources, (2) nuisance and aquatic life threatening pollutant sources, and (3) unpolluted water sources.

The pathogenic and toxic pollutant source category should be considered the most severe because it can cause illness upon water contact or consumption and significant water treatment problems for downstream consumers, especially if the pollutants are soluble metal and organic toxicants. These pollutants may originate from sanitary, commercial, and industrial wastewater non-stormwater entries. Other residential area sources (besides sanitary wastewater), e.g., inappropriate household toxicant disposal, automobile engine de-greasing, and excessive use of chemicals (fertilizers and pesticides) may also be considered in this most critical category.

Nuisance and aquatic life threatening pollutant sources can originate from residential areas and aside from raw sanitary wastewaters may include laundry wastewaters, lawn irrigation runoff, automobile washwaters, construction site dewatering, and washing of concrete ready-mix trucks. These pollutants can cause excessive dissolved oxygen depletions, and algal growths, tastes and odors in downstream water supplies, offensive coarse solids and floatables, and noticeably colored, turbid or odorous waters.

Clean water discharged through stormwater outfalls can originate from natural springs feeding urban creeks that have been converted to storm drains, infiltrating groundwater, infiltration from potable waterline leaks, etc.

Figure 1 is an outline of the major topics presented in this User's Guide, and Figure 2 is a simplified flow chart for the detailed methodology. The initial phase of the investigative protocol includes the initial mapping and field surveys. These activities require minimal effort and result in little chance of missing a seriously contaminated outfall. The initial activities are followed by more detailed watershed surveys to locate and correct the sources of the contamination in the identified problem areas. After corrective action has been taken, repeated outfall field surveys are required to ensure that the outfalls remain uncontaminated. Receiving water monitoring should also be conducted to analyze water quality improvements. If expected improvements are not noted, then additional contaminant sources are likely present and additional outfall and watershed surveys are needed.

MAPPING & PRELIMINARY WATERSHED EVALUATION (SECTION 3)

1) Identify receiving waters.
2) Locate all outfalls and associated drainage areas.
3) Compile data on land uses within drainage areas.

SELECTION OF TRACER PARAMETERS (SECTION 4)

1) Select physical and chemical parameters to measure.
2) Determine suitable analysis techniques and number of samples required.
3) Develop library of potential local source flow characteristics.

INITIAL FIELD SCREENING SAMPLING ACTIVITIES (SECTION 5)

1) Conduct outfall screening survey for intermittent and continuous flows.

DATA ANALYSIS TO IDENTIFY PROBLEM OUTFALLS AND FLOW COMPONENTS (SECTION 6)

1) Simple procedures using checklists for typical major flow components.
2) More detailed analyses utilizing library of data on potential source flows will quantify flow components.

WATERSHED SURVEYS TO CONFIRM AND LOCATE INAPPROPRIATE POLLUTANT ENTRIES TO THE STORM DRAINAGE SYSTEM (SECTION 7)

1) Conduct drainage surveys using tracer parameters in critical watersheds.
2) Use flow mass balances, dye studies, smoke tests, and T.V. surveys in isolated drainage areas.

CORRECTIVE TECHNIQUES (SECTION 8)

1) Educate public/industry and enforce with ordinances, zoning, etc.
2) Disconnect illicit direct connections.
3) Wide spread entries may require regional solutions or designation of storm drainage system as a CSO.

Figure 1. Outline of major topics presented in this User's Guide

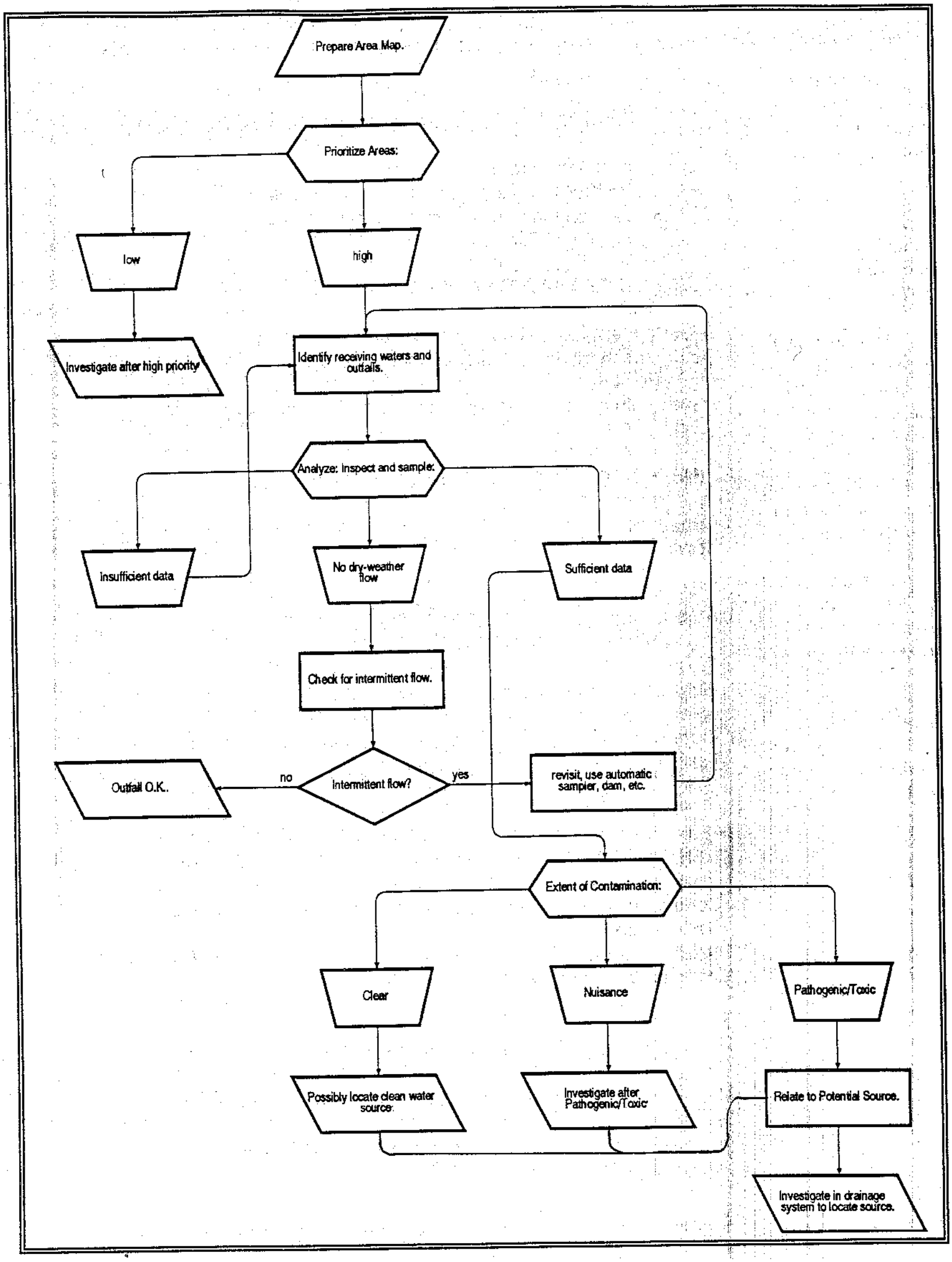

Figure 2. Flow chart for investigation procedures.

RECOMMENDATIONS

This User's Guide should be used as part of a comprehensive stormwater management plan which addresses all sources of stormwater pollution. Correction of pollutant entries identified by use of only this User's Guide is unlikely to achieve a significant improvement in the quality of stormwater discharges or receiving waters.

A municipality will need to plan their investigation of inappropriate entries to a storm drainage system to suit local conditions. This User's Guide describes the issues in sufficient depth and provides examples to enable the design of a local investigation. Greater detail and the results of a comprehensive demonstration of these procedures will be given in a supporting research report by Pitt and Lalor (publication pending).

The full use of all of the applicable procedures described in this User's Guide is likely to be required for successful identification of pollutant sources. Attempting to reduce costs, for example by only examining a certain class of outfalls, or using inappropriate testing procedures, will significantly reduce the utility of the testing program and result in inaccurate data. Also cursory data analyses is likely to result in inaccurate conclusions.

During investigations of non-stormwater entries to storm drainage systems, consideration should be given to any economic and practical advantages of designating the storm drainage system as a combined sewer systems and applying end-of-pipe combined sewer overflow (CSO) control-treatment.

It is also recommended that the methodology (appropriately modified) be applied to other types of sewerage systems, such as combined and separate sanitary sewerage systems, to locate inappropriate entries, e.g., untreated or toxic industrial wastewaters/wastes or infiltration/inflow (I/I) in separate sanitary sewers.

It is recommended that this User's Guide be updated and refined by incorporating experience gained in its application. Incorporation of information from a wide variety of test locations (e.g., lake and large river receiving waters, tidal receiving waters, areas experiencing long dry periods, areas having short summers, areas having unusual groundwater characteristics, etc.) will improve the testing and data analyses protocols described.

SECTION 3

MAPPING AND PRELIMINARY WATERSHED EVALUATION

PURPOSE

An investigation of non-stormwater entries into a storm drainage system needs to proceed along a systematic path of action, which investigates areas from high to low potential for causing problems, and focuses in from general outfall screening to pin-pointing pollutant sources.

A mapping and evaluation methodology, as detailed in this section, is required to identify the areas to investigate and to provide a basis to prioritize the areas by potential to contribute non-stormwater entries into the storm drainage system.

The data collected in this phase is important as it forms the basis for the rest of the more detailed investigations, described in the subsequent sections of this User's Guide.

MAPPING

To make this exercise as economical and productive as possible, full advantage should be taken of any existing and available information. Data gained from existing sources will need to be supplemented with information obtained by field investigations. The following summarizes the information required, likely data sources, and how to obtain the information.

Receiving Waters and Storm Sewer Outfalls

The receiving waters and stormwater drainage outfalls must be identified and accurately located on appropriate maps. However records of all outfalls are hard to locate, and even for those that can be found, the locations of the outfalls may not be accurate. It is therefore important that the field survey described in Section 5 be used to supplement the data collected during this initial stage. As noted in Section 5, it can take three visits to a drainage area to find all (or almost all) outfalls.

Possible sources of documented information include:

- City records, drainage maps, and storm drain maps.
- Previous surveys, e.g., sanitary sewer infiltration/inflow (I/I) and sewer system evaluation survey (SSES) studies.
- Topographic maps.
- Existing GIS (Geographic Information System) data.
- Pre-development stream locations.
- Drainage department personnel having knowledge of the area.
- Aerial surveys.

Drainage Area for Each Outfall

The drainage area for each outfall must be determined and marked on the map. This will enable known potential pollutant source locations to be assigned to the correct outfall. Sources for this information are storm drain maps and topographical maps. These should be at least 1" = 200' scale and have no greater than 5 ft contour intervals (depending on the steepness of the area).

Land Uses for Each Outfall Drainage Area

Local planning departments should have detailed zoning maps of the area. These maps should designate residential, commercial, and industrial land uses in each of the outfall drainage areas. In addition, local revenue departments should have lists of business licenses for the entire municipality, but they may not be usefully sorted. The public health department should know where septic tanks are used. Aerial photographs can provide useful information to identify and/or confirm land use areas. Historical land uses, especially landfills and industrial areas, should also be noted.

An effective way to obtain this information is to examine the municipality's zoning maps and to drive to the critical areas to conduct inspections. The land uses of most interest are all industrial, most commercial, and some municipal activities. The activities in the commercial areas of most concern include vehicle related activities (sales, parts, service, or repair), laundry or dry cleaning (including hospitals and hotels), and restaurants. The municipal activities of most concern include but are not limited to: landfills, bus barns, airports, and sanitary wastewater treatment facilities.

Table 2 can be used to identify the local industries in each drainage area most likely to contribute non-stormwater entries into the storm drainage system. The categories considered in this table include loading and unloading of dry bulk or liquid materials, outdoor storage or processing, water usage (cooling and process waters), dust or particulate generating processes, and illicit or inadvertent industrial connections. The likelihood of an industry producing dry-weather or wet-weather discharges in each of these categories was rated on the basis of high, moderate, or low potential and not applicable if there was no relationship evident.

The industrial categories listed in Table 2 were defined according to the 1987 Standard Industrial Classification Manual codes (SIC code). The industries were classified according to six main categories. The category for "Primary Industries" includes facilities involved in the production of food products and other basic goods. The category of "Material Manufacturing" includes those industries producing materials such as lumber, paper, glass, and leather. Similarly, the "Chemical Manufacturing" category includes those industries making products such as plastics, paints, detergents, fertilizers, pesticides, and other related substances. "Transportation and Construction" primarily concerns the discharge of contaminants from building or other types of outdoor development. The "Retail" category includes establishments engaged in the selling of merchandise or offering merchandise related services. Finally, all other industries which did not fit into any of the above classifications were placed into a "General" category. Those industries which are not specifically listed should have characteristics resembling the industries of the major groups with which they are classified by SIC code.

Investigators should take care to include any area where the land use has a potential to contribute pollutant sources to a storm drainage system. As stated above, these land uses may not be covered by Table 2. Some common examples of land use areas to be included are given below:

- Landfill areas can be a source of leachate and polluted runoff.
- Airports have a high potential for fuel spillage. Aircraft deicing agents, and other maintenance operations, produce wastewaters that may be discharged into the storm drainage system.

TABLE 2. SOURCES OF INDUSTRIAL NON-STORMWATER ENTRIES INTO STORM DRAINAGE SYSTEMS

Industrial Categories Major Classifications SIC Group Numbers			Loading/Unloading		Outdoor Storage/ Processing	Water Usage		Particle Generating Process	Illicit/ Inadvertent Connections
			Dry Bulk	Liquids		Cooling	Process		
Primary Industries									
20		Food & Kindred Products							
	201	Meat Products	H	L	H	H	H	L	H
	202	Dairy Products Processing Industry	H	H	NA	H	H	NA	H
	203	Canned & Preserved Fruits & Vegetables	H	H	H	H	H	M	H
	204	Grain Mill Products	H	H	L	H	H	H	H
	205	Bakery Products	H	M	NA	NA	H	M	L
	206	Sugar & Confectionary Products	H	M	NA	L	M	H	L
	207	Fats & Oils	H	H	NA	M	H	NA	M
	208	Beverages	H	H	NA	H	H	M	L
21		Tobacco Manufactures	H	M	NA	NA	M	H	M
22		Textile Mill Products	H	L	NA	H	H	M	H
23		Apparel & Other Finished Products Made from Fabrics & Similar Materials	H	L	NA	NA	M	M	L
Material Manufacture									
24		Lumber & Food Products	H	L	H	NA	M	H	L
25		Furniture & Fixtures	H	M	NA	NA	L	M	L
26		Paper & Allied Products	H	H	H	H	H	H	H
27		Printing, Publishing, & Allied Industries	H	M	NA	NA	M	H	L
31		Leather & Leather Products	H	H	L	L	H	H	H
32		Stone, Clay, Glass, & Concrete Products	H	M	H	L	H	H	L
33		Primary Metal Industries	H	M	H	H	H	H	H
34		Fabricated Metal Products	H	H	L	H	H	H	H
37		Transporation Equipment	L	H	L	H	H	L	H

(continued)

TABLE 2. (continued)

Industrial Categories Major Classifications SIC Group Numbers		Loading/Unloading		Outdoor Storage/ Processing	Water Usage		Particle Generating Process	Illicit/ Inadvertent Connections
		Dry Bulk	Liquids		Cooling	Process		
Chemical Manufacture								
28	Chemicals & Allied Products							
281	Industrial Inorganic Chemicals	H	H	NA	H	H	H	H
282	Plastic Materials & Synthetics	H	H	L	H	M	L	H
283	Drugs	L	L	NA	H	M	L	L
284	Soap, Detergents, & Cleaning Preparations	H	H	NA	H	H	H	H
285	Paints, Varnishes, Lacquers Enamels & Allied Products	H	H	NA	L	H	H	L
286	Industrial Organic Chemicals	H	H	NA	H	H	H	M
287	Agricultural Chemicals	L	L	NA	H	L	L	L
29	Petroleum Refining & Related Industries							
291	Petroleum Refining	L	H	H	H	L	NA	H
295	Paving & Roofing Materials	H	H	H	NA	M	M	L
30	Rubber & Misc. Plastic Products	H	H	NA	H	H	H	M
Transportation & Construction								
15	Building Construction	M	L	H	NA	L	H	L
16	Heavy Construction	M	L	H	NA	L	H	L
Retail								
52	Building Materials, Hardware Garden Supply, & Mobile Home Dealers	H	L	H	NA	L	NA	L
53	General Merchandise Stores	H	M	L	NA	L	NA	L
54	Food Stores	H	H	NA	NA	M	L	L
55	Automotive Dealers & Gasoline Service Stations	H	H	H	NA	M	L	M
56	Apparel & Accessory Stores	H	L	NA	NA	L	NA	L
57	Home Furniture, Furnishings and Equipment Stores	H	L	L	NA	L	NA	L
58	Eating & Drinking Places	H	M	NA	NA	M	NA	M
Other								
	Coal Steam Electric Power	H	L	H	H	L	H	L
	Nuclear Steam Electric Power	NA	L	NA	H	L	NA	NA

NOTE: H: High potential M Medium potential L Low potential NA: Not applicable

- Government facilities, such as military bases, may store or use polluting materials and have large vehicle maintenance facilities.
- Agricultural impacts are likely to be greater for wet-weather flows, but practices such as irrigation and drainage tiles may also produce dry-weather flows.

Finally, it is necessary to identify and locate existing permitted discharges to streams and storm drainage. The National Pollutant Discharge Elimination System (NPDES) permits, administered by most states or, if not, by the EPA Regional Offices, contain this information for the facilities currently having discharge permits. Only a small fraction of all industries have NPDES permits, as most have no direct wastewater discharges to waters of the United States. Pretreatment programs for municipal sewage treatment plants would also contain additional industrial information.

Other Relevant Information and Features

It is important that investigators be aware of any relevant features or information which may be specific to their drainage area and not included specifically in the above subsections of this User's Guide. Examples of some items that need to be included are discussed in this subsection.

Information on pre-development streams and springs, which may have been routed into the storm drainage system, will aid in the identification of natural uncontaminated or contaminated dry-weather flows.

Information regarding depth to the water table will be helpful. If the water table is well below the storm drain invert at all times, then groundwater infiltration may be less important as a potential source of dry-weather flow. However, the accumulation of percolating shallow groundwater will still occur in storm drainage fill material and be a potential source of some infiltration water. Groundwater conditions for the study area may be available from special studies conducted by the USGS (U.S. Geological Survey), the state water agency, or other sources. Utility construction and repair crews and earth moving companies should know of areas having shallow groundwater. Local I/I and SSES studies also include information concerning shallow groundwater. Well log data collected during drilling of water supply wells, and information from geotechnical investigations, may also be useful.

Areas serviced by sanitary sewerage and areas serviced by septic tanks should be determined in order to identify the areas most likely to have direct connections and infiltration sources, respectively. Either local health, sewerage, utility, environmental, or public works departments should have information on the location of these areas.

Older residential areas with failing infrastructure (especially sanitary sewerage in poor condition), and high density residential areas with septic tanks, should be designated as areas with a high potential for pollutant entries into the storm drainage system.

PRELIMINARY WATERSHED EVALUATION

The above activities should produce maps with complete descriptions of the drainage areas, including outfall locations, NPDES permittees, critical land uses, drainage boundaries for each outfall, city limits, major streets, streams, etc. The investigators need to classify drainage areas by their potential for causing non-stormwater entries. This mapping information, together with the information to be obtained as described in Sections 4 and 5 and analyzed as described in Section 6, will form the basis to rank the drainage areas in order of priority for further detailed drainage area investigations (Sections 7 and 8).

The investigation of non-stormwater entries will have a cost associated with it, which will increase with the drainage system size and complexity, and with the number of sources being investigated. All pollutant sources, including both wet- and dry-weather pollutant entries, will need to be controlled to have an effective improvement in the quality of the stormwater system discharge. Pitt and McLean (1986) noted that even with the removal of directly connected non-stormwater entries, stormwater originating from industrial and commercial land uses has a high probability of having unacceptable pollutant loads. It would therefore be prudent, at an early stage in the investigation, to review the costs of the investigation and corrective action versus the cost for treatment of the stormwater system discharge. The classification of the storm drainage system as a combined sewer, and subsequent treatment of the flow, may prove to be a more economical and practical alternative. An appropriate time for such a review would be after the mapping and field screening activities to avoid complex, costly, and time consuming drainage system investigations into inappropriate non-stormwater entries, and instead direct resources to pollution control.

SECTION 4

SELECTION OF TRACER PARAMETERS

INTRODUCTION

The detection and identification of inappropriate entries requires the quantification of specific characteristics of the observed outfall baseflow. The characteristics of most interest should be relatively unique for each potential flow source. This will enable the presence of each flow source to be noted, based on the presence (or absence) of these unique characteristics. The selected characteristics are termed tracers, because they have been selected to enable the identification of the sources of these waters.

One approach presented in this User's Guide is based on the identification and quantification of clean baseflow and contaminated components. If the relative amounts of potential components are known, then the importance of the baseflow can be determined. As an example, if a baseflow is mostly uncontaminated groundwater, but contains 5 percent raw sanitary wastewater, it would be a likely important source of pathogenic bacteria. Typical raw sanitary wastewater parameters (e.g., BOD_5 or suspended solids) would be in low concentrations and the sanitary wastewater source would be difficult to detect. Fecal coliform bacteria measurements would not help much because they originate from many possible sources. Expensive specific pathogen measurements would be needed to detect the problem directly.

The ideal tracer should have the following characteristics:

- Significant difference in concentrations between possible pollutant sources;
- Small variations in concentrations within each likely pollutant source category;
- A conservative behavior (i.e., no significant concentration change due to physical, chemical or biological processes); and,
- Ease of measurement with adequate detection limits, good sensitivity, and repeatability.

In order to identify tracers meeting the above criteria, literature characterizing potential inappropriate entries into storm drainage systems was examined. Several case studies which identified procedures used by individual municipalities or regional agencies were also examined. Though most of the investigations resorted to expensive and time consuming smoke or dye testing to locate individual illicit pollutant entries, a few provided information regarding test parameters or tracers. These screening tests were proven useful in identifying drainage systems with problems before the smoke and dye tests were used. The case studies also revealed the types of illicit pollutant entries most commonly found in storm drainage systems.

This list of potential illicit sources (see Section 2) led to a search for information regarding the chemical and physical characteristics of these specific flows. This search yielded typical characteristics for sanitary wastewater, septic tank effluent, coin-operated laundries and car wash effluents as well as potable water and "natural waters". This information, along with specifics obtained from case studies, provided the basis for selecting parameters for further study. Specific analyses will be needed to identify the characteristics of local potential inappropriate entries and uncontaminated water sources, as described in this section.

CANDIDATE PARAMETERS

Many different candidate parameters were evaluated before the suggested list was developed (Pitt and Lalor publication pending). It is recommended that the initial field screening effort (in the absence of known commercial and industrial activities in the watershed) include at least:

- Placement of outfall identification number.
- Outfall discharge flow estimate.
- Floatables, coarse solids, color, turbidity, oil sheen, and odor characteristics of discharge and/or receiving nearfield water.
- Other outfall area characteristics, e.g., stains, debris, damage to concrete, corrosion, unusual plant growth, or absence of plants.
- Water temperature.
- Specific conductivity.
- Fluoride and/or hardness concentrations.
- Ammonia and/or potassium concentrations.
- Surfactant concentration and/or fluorescence.
- Chlorine concentration and pH.

If commercial or industrial activities occur in the drainage area, then it is important to add additional parameters (e.g., a toxicity screening procedure and specific metallic and organic toxicant analyses) to the above list.

Most of the screening effort items listed above can be obtained at the outfall location using field procedures. It is much easier, more cost-effective, and much more accurate to collect samples in the field for later laboratory analyses. Analyzing multiple samples for the same parameter is much more efficient than trying to analyze a single sample for many parameters, especially under adverse field conditions.

The selection of the analysis procedures and equipment will depend on many conditions, most notably the expected concentrations in the uncontaminated baseflows and in the potential non-stormwater discharge flows, along with the needed probabilities of detection at the minimum contamination level. A description of the techniques developed as part of this study to help in the selection of the analytical procedures is given later in this section. Other factors affecting procedure selection include ease of use, analytical interferences, cost of equipment, training requirements, and time requirements to conduct the analyses.

Physical Inspection

Estimates of outfall flow rates, and noting the presence of oil sheens, floatables, coarse solids, color, odors, etc. will probably be the most useful indicators of outfall problems. Physical observations of outfall conditions have been noted in case studies to be very useful in determining the significance of contaminated dry-weather flows. There has been a good correlation between storm drains judged contaminated after physical inspection and those judged contaminated after chemical tests at several case studies (e.g., Inner Grays Harbor, Washington, Beyer, et al. 1979 and Pelletier and Determan 1988; Fort Worth, Texas, Falkenbury 1987 and 1988 and Moore and Hoffpauir 1988; and Toronto, Ontario, GLA 1983).

Odor--

The odor of a discharge can vary widely and sometimes directly reflects the source of contamination. Industrial dry-weather discharges will often cause the flow to smell like a particular spoiled product, oil, gasoline, specific chemical, or solvent. As an example, for many industries, the decomposition of organic wastes in the discharge will release sulfide compounds into the air above the flow in the sewer, creating an intense smell of rotten eggs. In particular, industries involved in the production of meats, dairy products, and the preservation of vegetables or fruits, are commonly found to discharge organic materials into storm drains. As these organic materials spoil and decay, the sulfide production creates this highly apparent and unpleasant smell. Significant sanitary wastewater contributions to a dry-weather flow will also cause pronounced and distinctive odors.

Color--

Color is another important indicator of inappropriate discharges, especially from industrial sources. Industrial dry-weather discharges can have various colors. Dark colors, such as brown, gray, or black, are most common. For instance, the color contributed by meat processing industries is usually a deep reddish-brown. Paper mill wastes are also brown. In contrast, textile wastes are varied. Other intense colors, such as plating-mill wastes, are often yellow. Washing of work areas in cement and stone working plants can cause cloudy dry-weather discharges. Potential dry-weather sources causing various colored contaminated waters from industrial areas include process waters (slug or continuous discharges), equipment and work area cleaning water discharged to floor drains, and spills during loading operations (and subsequent washing of the material into the storm drains).

Turbidity--

Turbidity of water is often affected by the degree of gross contamination. Dry-weather industrial flows with moderate turbidity can be cloudy, while highly turbid flows can be opaque. High turbidity is often a characteristic of undiluted dry-weather industrial discharges, such as those coming from some continual flow sources, or some intermittent spills. Sanitary wastewater is also often cloudy in nature.

Temperature--

Temperature measurements may be useful in situations where the screening activities are conducted during cold months, or in areas having industrial activity. It may be possible to identify an outfall that is grossly contaminated with sanitary wastewater or cooling water during cold weather and possibly to conduct a rough heat balance. Both sanitary wastewater and cooling water could substantially increase outfall discharge temperatures. Elevated baseflow temperatures (compared to baseflows at other outfalls being screened) could be an indicator of substantial contamination by these warmer source flows.

Floatable Matter--

A contaminated flow may also contain floatables (floating solids or liquids). Evaluation of floatables often leads to the identity of the source of industrial or sanitary wastewater pollution, since these substances are usually direct products or byproducts of the manufacturing process, or distinctive of sanitary wastewater. Floatables of industrial origin may include substances such as animal fats, spoiled food products, oils, plant parts, solvents, sawdust, foams, packing materials, or fuel; whereas floatables in sanitary wastewater include fecal matter, sanitary napkins, and condoms.

Deposits and Stains--

Deposits and stains (residue) refer to any type of coating which remains after a non-stormwater discharge has ceased. They will cover the area surrounding the outfall and are usually of a dark color. Deposits and stains often will contain fragments of floatable substances and, at times, take the form of a crystalline or amorphous powder. These situations are illustrated by the grayish-black deposits that contain fragments of animal flesh and hair which often are produced by leather tanneries, or the white crystalline powder which commonly coats sewer outfalls due to nitrogenous fertilizer wastes.

Vegetation--

Vegetation surrounding an outfall may show the effects of intermittent or random non-stormwater discharges. Industrial pollutants will often cause a substantial alteration in the chemical composition and pH of the discharge. This alteration will affect plant growth, even when the source of contamination is intermittent. For example, decaying organic materials coming from various food product wastes could cause an increase in plant life. In contrast, the discharge of chemical dyes and inorganic pigments from textile mills could noticeably stunt plant growth, as these dry-weather discharges are often acidic. In either case, when the industrial pollution constituent in the flow ceases, the vegetation surrounding the outfall will continue to show the effects of the contamination.

In order to accurately judge if the vegetation surrounding an outfall is normal, the observer must take into account the current weather conditions, as well as the time of year in the area. Thus, flourishing or inhibited plant growth, as well as dead and decaying plant life, are all signs of pollution or scouring flows when the condition of the vegetation beyond the outfall contrasts with the plant conditions near the outfall. It is important not to confuse the adverse effects of high storm-induced flows on vegetation with highly toxic dry-weather intermittent flows. Poor plant growth could be associated with scouring flows occurring during storms.

Damage to Sewerage/Outfall Structure--

Sewerage structural damage is another readily visible indication of both continual and intermittent industrial dry-weather discharge contamination. Cracking, deterioration, and spalling of concrete or peeling of surface paint, occurring at an outfall are usually caused by severely contaminated discharges, usually of industrial origin. These contaminants are usually very acidic or basic in nature. For instance, primary metal industries have a strong potential for causing sewerage structural damage because their batch dumps are highly acidic. However confusion is possible due to the effects poor construction, hydraulic scour, and old age may have had on the condition of the outfall structure or sewerage system.

Chemical Parameters

Chemical tests are needed to supplement the above described physical inspection parameters. Chemical tests are needed to quantify the approximate components of a mixture at the outfall. In most cases, dry-weather discharges are made up of many separate source flows (e.g., potable water, groundwaters, sanitary wastewater, and automobile washwaters). Statistical analyses of the chemical test results can be used to estimate the relative magnitudes of the various flow sources (as described in Section 6 of this Guide).

Specific Conductivity--

Specific conductivity can be used as an indicator of dissolved solids. Specific conductivity measurements can be conducted with relative ease in the field, while dissolved solids measurements must be made in a laboratory.

The literature indicates that variation in specific conductivity measurements between water and wastewater sources could be substantial enough to indicate the source of dry-weather flow in the storm drainage system. Specific conductance was judged to be a reliable and quick field indicator of general outfall contamination in Toronto (GLA 1983). Observed levels ranged from 25 to 100,000 μS/cm (microSiemens per cm). Specific conductivity levels less than 1000 μS/cm indicated significant levels of rainwater in the drainage. Specific conductivity can be measured quickly, easily and cheaply. For these reasons, it was selected as a parameter for further study.

Fluoride--

Fluoride concentration should be a reliable indicator of potable water where fluoride levels in the raw water supply are adjusted to consistent levels and where groundwater has low to non-measurable natural fluoride levels. It is common practice for communities to add fluoride to municipal waters to improve dental health. Concentrations of total fluoride in fluoride treated potable waters are usually in the range of 1.0 to 2.5 mg/L.

Fluoride measurements have often been used to distinguish treated waters from natural waters. During the Allen Creek drainage study (Schmidt and Spencer 1986), the fluoride concentrations of dry-weather flows at outfalls were undetectable after most of the known improper connections to storm drains were eliminated. Very few of these improper connections were of sanitary wastewater to the storm drainage. Apparently, most of the non-stormwater discharges were treated potable water.

Hardness--

Hardness may also be useful in distinguishing between natural and treated waters (like fluoride), as well as between clean treated waters and waters that have been subjected to domestic use.

The hardness of waters varies considerably from place to place, with groundwaters generally being harder than surface waters. Natural sources of hardness are limestones which are dissolved by percolating rainwater made acid by dissolved carbon dioxide. Information regarding the average hardness of potable water as well as local groundwater and surface waters should be readily available wherever a public water supply system exists.

Ammonia/Ammonium--

As part of the nitrogen cycle, ammonia is produced by the decay of organic nitrogen compounds. Ammonia may then be broken down, forming nitrites and nitrates. The presence or absence of ammonia (NH_3), or ammonium ion (NH_4^+), has been commonly used as a chemical indicator for prioritizing sanitary wastewater cross-connection drainage problems. Correlations between elimination of improper sanitary wastewater cross-connections into storm drainage and reduced numbers of storm drainage outfalls with ammonia present were noted in Fort Worth (Falkenbury 1987 and 1988; Moore and Hoffpauir 1988). During studies in Toronto (GLA 1983), more "problem" storm drain outfalls had high ammonia concentrations (>1 mg/L) than any other single parameter, except TKN. During the Huron River (Michigan) study (Washtenaw Co. 1987 and 1988; Murray 1985), ammonia levels were found to be greater at all "problem" storm drain outfalls than at control locations. However, the Allen Creek (Michigan) Drainage study (Schmidt and Spencer 1986) reported that with 92 percent of the improper non-stormwater entries to storm drains eliminated, the ammonia concentrations did not change significantly (all were about 0.44 mg/L). However, very few of these cross-connection eliminations were for sanitary wastewater. Ammonia should be useful in identifying sanitary wastes and distinguishing them from commercial water usage.

Potassium--

Large increases of potassium concentrations have been noted for sanitary wastewater compared to potable water during studies in California (Evans 1968), Virginia (Hypes, et al. 1975), and Brussels, Belgium (Verbanck, et al. 1990). These potassium increases following domestic water usage suggest its potential as a tracer parameter.

Surfactants and Fluorescence--

Surfactants are discharged from household and industrial laundering and other cleaning operations. In the United States, anionic surfactants are commonly used in detergents and account for approximately two thirds of the total surfactants used. Anionic surfactants are commonly measured as Methylene Blue Active Substances (MBAS). In raw sanitary wastewaters, surfactants generally range from 1 to 20 mg/L, while natural waters usually have surfactant concentrations below 0.1 mg/L.

Large concentrations of surfactants are found in sanitary wastewater, but some researchers (Alhajjar, et al. 1989) have reported that they are not found in septic tank effluent. Surfactants can be totally degraded in the septic tanks. During the Allen Creek drainage study (Schmidt and Spencer 1986; Washtenaw County Drain Commissioner 1984; and Washtenaw County Statutory Drainage Board 1987), surfactants (as MBAS) decreased significantly after most of the improper non-stormwater entries to storm drains were eliminated. Surfactants can be used to identify sanitary or laundry wastewater cross-contamination in storm drainage systems. They may also be of use in distinguishing between infiltrating septic tank effluent and other washwaters from domestic or commercial cleaning operations.

Water fluorescence is also an indicator of detergent residue in waters. Most detergents contain fabric whiteners which cause substantial fluorescence. Fluorescent indicators remain after sanitary wastewater treatment in septic tanks. Fluorescence in contrast to MBAS may be useful in distinguishing between sanitary wastewater contamination and septic tank effluent.

pH--

The pH of most uncontaminated baseflows, as well as sanitary wastewater, is usually quite close to neutral (pH of 7). Therefore, Ph will probably not serve as an indicator of sanitary cross connections. However, pH values may be extreme in certain inappropriate commercial and industrial flows or where groundwaters contain dissolved minerals. If unusual pH values are observed, then the drainage system needs to be carefully evaluated. Very few of the stormwater outfalls tested during dry-weather in Fort Worth (Falkenbury 1987 and 1988; Moore and Hoffpauir 1988) had pH values either below 6 or above 9. None of the Toronto (GLA 1983) "problem" outfalls were reported to have extreme pH values.

Chemicals (acidic and alkaline) released into storm drains by chemically-oriented industries are frequently the cause of pH fluctuations which can range from 3 to 12.

Industries that commonly release low pH (acidic) dry-weather discharges include (but are not limited to) textile mills, pharmaceutical manufacturers, metal finishers/fabricators, as well as companies producing resins, fertilizers and pesticides. Wastes containing sulfuric, hydrochloric, or nitric acids are common industrial sources of low pH discharges.

Many industrial wastes contain high pH (alkaline) chemicals such as cyanide, sodium sulfide, and sodium hydroxide. High concentrations of these contaminants are found in discharges from soap manufacturers, textile mills, metal plating industries, steel mills, and producers of rubber or plastic.

Total Available Chlorine--

Chlorine can be present in water as free available chlorine and as combined available chlorine (usually as chloramines). Both types can exist in the same water and be determined together as the total available chlorine. Chlorine is not stable in water, especially in the presence of organic compounds. Tests of clean potable water during the demonstration project (Pitt and Lalor publication pending) found that total available chlorine only decreased by about 25 percent in 24-hours during an aerated bench-scale test. However, the chlorine demand of contaminated water can be very large, with chlorine concentrations decreasing to very small values after short periods of time. Chlorine therefore cannot be used to quantify flow sources because of its instability, but the presence of chlorine in baseflow waters (very unlikely) could indicate a significant and very close potable water flow source.

Other Chemicals Indicative of Manufacturing Industrial Activities--

Table 3 is a listing of various chemicals that may be associated with a variety of different industrial activities. If the industrial activities in an outfall watershed are known, it may be possible to examine the non-stormwater outfall flow for specific chemicals (e.g., listed in Table 3) to identify which industrial activities may be responsible for the dry-weather flow.

TABLE 3. SIGNIFICANT CHEMICALS IN INDUSTRIAL WASTEWATERS

Chemical:	Industry:
Acetic acid	Acetate rayon, pickle and beetroot manufacture.
Alkalies	Cotton and straw kiering, cotton manufacture, mercerizing, wool scouring, and laundries.
Ammonia	Gas, coke, and chemical manufacture.
Arsenic	Sheep-dipping, and felt mongering.
Chlorine	Laundries, paper mills, and textile bleaching.
Chromium	Plating, chrome tanning, and aluminum anodizing.
Cadmium	Plating.
Citric acid	Soft drinks and citrus fruit processing.
Copper	Plating, pickling, and rayon manufacture.
Cyanides	Plating, metal cleaning, case-hardening, and gas manufacture.
Fats, oils	Wool scouring, laundries, textiles,and oil refineries.
Fluorides	Gas, coke, and chemical manufacture, fertilizer plants, transistor manufacture, metal refining, ceramic plants, and glass etching.
Formalin	Manufacture of synthetic resins and penicillin.
Hydrocarbons	Petrochemical and rubber factories.
Hydrogen peroxide	Textile bleaching, and rocket motor testing.
Lead	Battery manufacture, lead mining, paint manufacture, and gasoline manufacture.
Mercaptans	Oil refining, and pulp mills.
Mineral acids	Chemical manufacture, mines, Fe and Cu pickling, brewing, textiles, photo-engraving, and battery manufacture.
Nickel	Plating.
Nitro compounds	Explosives and chemical works.
Organic acids	Distilleries and fermentation plants.
Phenols	Gas and coke manufacture, synthetic resin manufacture, textiles, tanneries, tar, chemical, and dye manufacture and sheep-dipping.
Silver	Plating, and photography.
Starch	Food, textile, and wallpaper manufacture.
Sugars	Dairies, foods, sugar refining, and preserves.
Sulfides	Textiles, tanneries, gas manufacture, and rayon manufacture.
Sulfites	Wood process, viscose manufacture, and bleaching.
Tannic acid	Tanning, and sawmills.
Tartaric acid	Dyeing, wine, leather, and chemical manufacture.
Zinc	Galvanizing, plating, viscose manufacture, and rubber process.

Source: Van der Leeden, et al. 1990.

Toxicity Screening Tests

In addition to the parameters described above, relative toxicity can be an important outfall screening parameter. Short-term toxicity tests, such as the Microtox™ test (from Microbics) are valuable for quickly and cheaply assessing the relative toxicity (to a selected test organism) of different storm drain baseflows. These tests can be used to identify outfalls that contain flows in the most serious (toxic) category and that require immediate investigation. These tests are also very useful in identifying likely sources of toxicants to the drainage system by utilizing a toxicity reduction evaluation (TRE) procedure in the drainage system. If an outfall contains a highly toxic flow, then specific metallic and organic toxicants can be analyzed to support source identification.

TRACER CHARACTERISTICS OF SOURCE FLOWS

Table 4 summarizes the relative concentrations of tracer parameters in source flows. The unique "fingerprints" of each flow category shown can be used to identify the flow components, as shown in Section 6. This table also contains redundancies, (e.g., potassium and ammonia) to help identify sanitary wastewater and septic tank effluent. Fluoride and hardness are similarly used to identify treated potable water and surfactant (MBAS) and fluorescent measurements are used to identify washwaters.

Table 5 is a summary of the tracer parameter concentrations found in Birmingham, Alabama, from April 1991 to September 1992. This table is a summary of the "library" that describes the tracer conditions for each potential source category. The important information shown on this table includes the median and coefficient of variation (COV) values for each tracer parameter for each source category. The COV is the ratio of the standard deviation to the mean. A low COV value indicates a smaller spread of data compared to a data set having a large COV value. It is apparent that some of the abstracted and generalized relationships shown on Table 4 did not exist during the demonstration project. This stresses the need for obtaining local data describing likely source flows.

The fluorescence values shown on Table 5 are direct measurements from the Turner™ (Model 111) fluorometer having general purpose filters and lamps and at the least sensitive setting (number 1 aperture). The toxicity screening test results are expressed as the toxicity response noted after 25 minutes of exposure. The Microtox™ unit measures the light output from phosphorescent algae. The I_{25} value is the percentage light output decrease observed after 25 minutes of exposure to the sample. If an outfall sample has a very high light reduction value, it is typically subjected to additional organic and metallic toxicant tests. Fresh potable water has a relatively high response because of the chlorine levels present. Aged, or dechlorinated, potable water has much smaller toxicity responses.

Appropriate tracers are characterized by having significantly different concentrations in flow source categories requiring identification. In addition, effective tracers also need low COV values within each flow category. Table 4 indicates the expected changes in concentrations per category and Table 5 indicates how these expectations compared with the results of an extensive local sampling effort. The study indicated that the COV values were quite low for each category, with the exception of chlorine, which had much greater COV values. The high chlorine COV values reinforce what was previously indicated (under Total Available Chlorine), that chlorine is not recommended as a quantitative tracer to estimate the flow components. Similar data must be collected in each community where these procedures are to be used. The following subsection discusses how the number of samples needed per category can be estimated.

TABLE 4. FIELD SURVEY PARAMETERS AND ASSOCIATED NON-STORMWATER FLOW SOURCE CATEGORIES

Parameter	Natural Water	Potable Water	Sanitary Wastewater	Septic Tank Effluent	Indus. Water	Wash-Water	Rinse Water	Irrig. Water
Fluorides	-	+	+	+	+/-	+	+	
Hardness Change	-	+/-	+	+	+/-	+	+	+
Surfactants	-	-	+	-	-	+	-	-
Fluorescence	-	-	+	+	-	+	-	-
Potassium	-	-	+	+	-	-	-	-
Ammonia	-	-	+	+	-	-	-	-
Odor	-	-	+	+	+	+/-	-	-
Color	-	-	-	-	+	-	-	-
Clarity	-	-	+	+	+	+	+/-	-
Floatables	-	-	+	-	+	+/-	+/-	-
Deposits/Stains	-	-	+	-	+	+/-	+/-	-
Vegetation Change	-	-	+	+	+	+/-	-	+
Structural Damage	-	-	-	-	+	-	-	-
Conductivity	-	-	+	+	+	+/-	+	+
Temperature Change	-	-	+/-	-	+	+/-	+/-	-
pH	-	-	-	-	+	-	-	-

NOTE:
- \- implies relatively low concentration
- \+ implies relatively high concentration
- +/- implies variable conditions

TABLE 5. TRACER CONCENTRATION FOUND IN BIRMINGHAM, ALABAMA WATERS (MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION, COV)

	Spring Water	Treated Potable Water	Laundry Waste-water	Sanitary Waste-water	Septic Tank Effl.	Car Wash-water	Radiator Flush Water
Fluorescence (% scale)	6.8 2.9 0.43	4.6 0.35 0.08	1020 125 0.12	250 50 0.20	430 100 0.23	1200 130 0.11	22,000 950 0.04
Potassium (mg/L)	0.73 0.070 0.10	1.6 0.059 0.04	3.5 0.38 0.11	6.0 1.4 0.23	20 9.5 0.47	43 16 0.37	2800 375 0.13
Ammonia (mg/L)	0.009 0.016 1.7	0.028 0.006 0.23	0.82 0.12 0.14	10 3.3 0.34	90 40 0.44	0.24 0.066 0.28	0.03 0.01 0.3
Fluoride (mg/L)	0.031 0.027 0.87	0.97 0.014 0.02	33 13 0.38	0.77 0.17 0.23	0.99 0.33 0.33	12 2.4 0.20	150 24 0.16
Toxicity (% light decrease after 25 min., I[25])	<5 n/a n/a	47 20 0.44	99.9 <1 n/a	43 26 0.59	99.9 <1 n/a	99.9 <1 n/a	99.9 <1 n/a
Surfactants (mg/L as MBAS)	<0.5 n/a n/a	<0.5 n/a n/a	27 6.7 0.25	1.5 1.2 0.82	3.1 4.8 1.5	49 5.1 0.11	15 1.6 0.11
Hardness (mg/L)	240 7.8 0.03	49 1.4 0.03	14 8.0 0.57	140 15 0.11	235 150 0.64	160 9.2 0.06	50 1.5 0.03
pH (pH units)	7.0 0.05 0.01	6.9 0.29 0.04	9.1 0.35 0.04	7.1 0.13 0.02	6.8 0.34 0.05	6.7 0.22 0.03	7.0 0.39 0.06
Color (color units)	<1 n/a n/a	<1 n/a n/a	47 12 0.27	38 21 0.55	59 25 0.41	220 78 0.35	3000 44 0.02
Chlorine (mg/L)	0.003 0.005 1.6	0.88 0.60 0.68	0.40 0.10 0.26	0.014 0.020 1.4	0.013 0.013 1.0	0.070 0.080 1.1	0.03 0.016 0.52
Spec. Conduct. (μS/cm)	300 12 0.04	110 1.1 0.01	560 120 0.21	420 55 0.13	430 311 0.72	485 29 0.06	3300 700 0.22
Number of Samples	10	10	10	36	9	10	10

Determining Number of Observations Needed

It is very important to determine the number of observations needed for each tracer parameter for each source category in order to build a useful data library for analyzing the outfall data. This determination is a function of the tolerable error level in the data means and the standard deviations. The following paragraphs briefly describe a method that can be used to estimate the sampling effort needed to develop a useful library of source characteristic data.

Estimating Errors--

One equation that can be used to calculate the number of analyses needed, based on the allowable error is (Cochran 1963):

Number of samples $= 4(\text{standard deviation})^2/(\text{allowable error})^2$

With a 95 percent level of confidence, this relationship determines the number of samples needed to obtain a value within the range of the sample mean, plus and minus the error. Similarly, this equation can be used to predict the 95 percent confidence interval, based on the measured (or estimated) standard deviation and number of samples obtained:

$$\text{Error} = 2(\text{standard deviation})/(\text{number of samples})^{0.5}$$

where the confidence interval is the mean plus and minus the calculated error value.

Example of Log_{10} Transformation--

These equations assume a normal distribution of the data. However, most water quality data needs to be $\log_{10}$ transformed before a normal distribution is obtained. As an example, consider a tracer having a COV of 0.23 and a median value of 0.14. The resulting $\log_{10}$ transformed standard deviation would be about 0.12. For ten samples, the resulting 95 percent confidence range of the median observation (0.14 mg/L) is:

$$\text{Error} = 2(0.12)/(10)^{0.5} = 0.076 \text{ in } \log_{10} \text{ space}$$

The confidence interval is therefore $\log_{10}(0.14)$ +/- 0.076, which is -0.778 to -0.930 in log10 space. This results in a conventional 95 percent confidence range of $10^{-0.930}$ (= 0.12) to $10^{-0.778}$ (= 0.17). The error in the estimate of the median value is therefore between 14 and 21% for ten samples. If the original untransformed data were used, the error associated with 10 samples is 15%, within the range of the estimate after log transformations. These results are close because of the low COV value (0.23). If the COV value is large, the need for log transformations increases. Figure 3 (Pitt 1979) shows the approximate sample size needed to obtain different allowable errors for different COV values (using nontransformed data).

The COV value in the above example (0.23) was close to the median COV value for all of the source categories and tracer parameters shown on Table 5. Therefore, about 10 samples per source flow category should generally result in less than a 25 percent error for the median values obtained.

As shown in a later section, narrow confidence intervals are needed in order to estimate the relative mixes of the non-stormwater sources as measured at the outfall. Therefore, much care needs to be taken in order to estimate the characteristics of the potential non-stormwater flow sources, especially the COV values and medians.

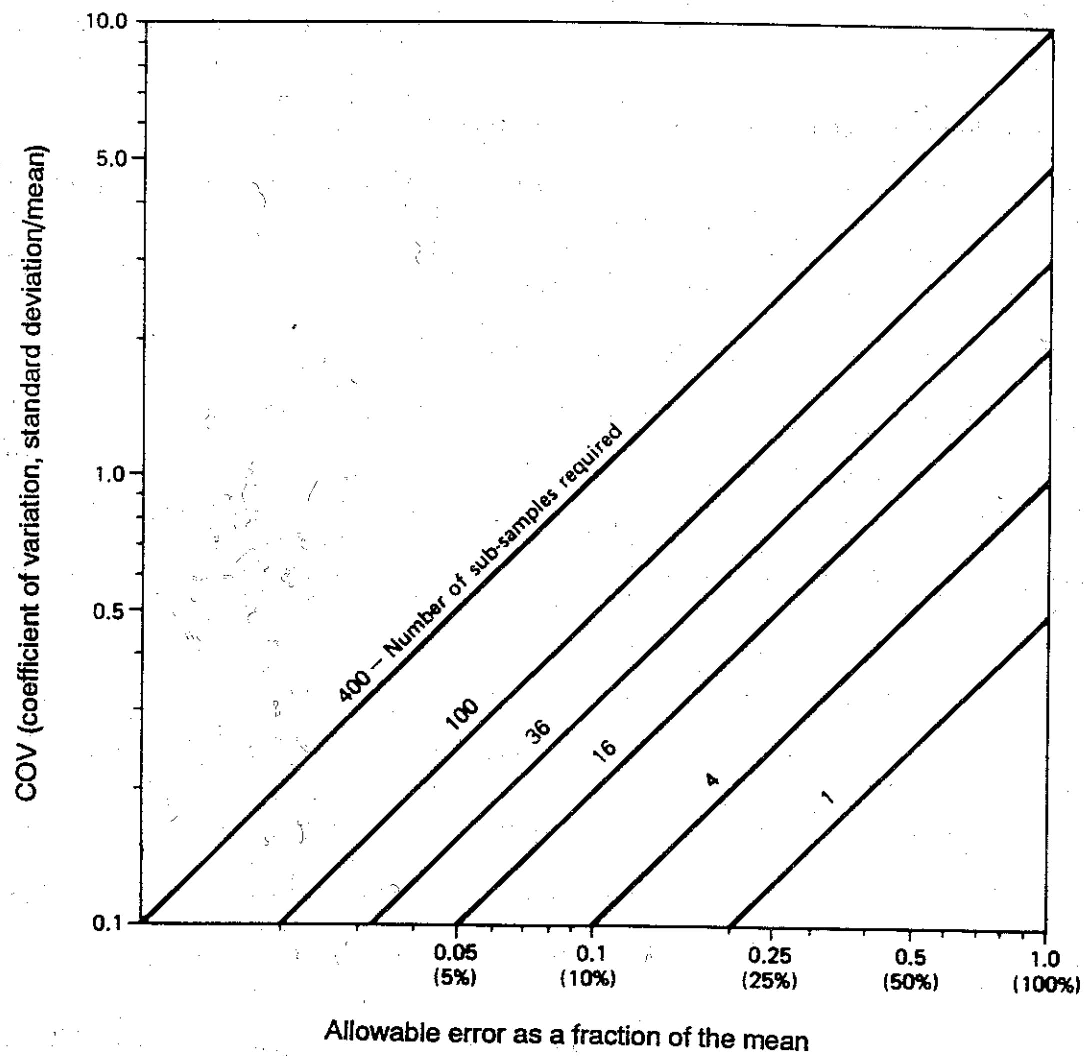

Figure 3. Required number of samples for allowable error and COV

Source: Pitt 1979

Understanding the mechanisms affecting the non-stormwater sources (e.g., time of day, season, area of town, type and magnitude of land use activities, etc.) and obtaining a relatively large data base library for the source flow tracer concentrations is very important and should be a significant portion of a dry-weather flow source identification project.

SELECTION OF ANALYTICAL METHODS

The selection of the analytical procedure to be used is dependent on a number of factors, including (in order of importance):

- appropriate detection limits
- freedom from interferences
- good analytical precision (repeatability)
- low cost and good durability
- minimal operator training required

The following sub-sections discuss these requirements and present the recommended analytical procedures. Tracer characteristics in potential local source flows affect most of these requirements. Therefore, the suggested analytical procedures may not be the most cost-effective for all areas.

Detection Limit Requirements

In order to identify potential non-stormwater sources, it is necessary to have a basic knowledge about each potential source flow. As shown earlier, a significant sampling and analysis effort is needed to develop a library of source flow tracer concentrations. The COVs and means of the tracer concentrations are needed to estimate the detection limits required by the analytical procedures.

There are a number of different types of detection limits defined for laboratory use. Most instrument manufactures present a minimum readable value as the instrument detection limit (IDL) in their specifications for simple test kits. The usual definition of IDL, however, is a concentration that produces a signal to noise ratio of five. The method detection limit (MDL) is a more conservative value and is established for the complete preparation and analysis procedure. The practical quantification limit (PQL) is higher yet and is defined as a routinely achievable detection limit with a relatively good certainty that any reported value is reliable. Standard Methods (APHA, et al. 1989) estimates that the relationship between these detection limits is approximately: IDL:MDL:PQL = 1:4:20. Therefore, the detection limit shown in much of the manufacturer's literature is much less than what would be used by most analytical laboratories.

Because of the screening nature of the outfall field surveys, the instrument detection capabilities are appropriate for the methodology described in this Users' Guide. The larger uncontrollable errors associated with obtaining representative outfall samples and in the variations of the tracer concentrations in the potential source flows would tend to diminish the significance of errors associated with reading concentration values from the instrument that are lower than the PQL.

A quick (and conservative) estimate of the needed detection limit can be made by only knowing the median concentration and the concentration variation of the tracer in the least contaminated component flow. Any amount of another component having a greater tracer concentration will increase the tracer concentration of the mixture. By ignoring this increase, minimum detection limits can be estimated based on the numerous probability calculations presented in the background demonstration project report (Pitt and Lalor publication pending):

COV value:	Multiplier for detection limit:
<0.5 (low)	0.8
0.5 to 1.25 (medium)	0.23
>1.25 (high)	0.12

As an example, if the baseflow tracer has a low COV (<0.5), then the estimated required detection limit is about 0.8 times the median tracer concentration.

More than 80 percent of the library categories (source flows and tracers) examined in Birmingham, Alabama during the demonstration of these procedures (shown on Table 5) had low COV values. About 15 percent had medium COV values, and about 5 percent had high COV values. Free available chlorine had medium or high COV values for almost all source categories. This is a major reason why chlorine is not used quantitatively to identify source flow components in outfall samples. Chlorine is used in a similar manner as an aesthetic parameter (e.g., turbidity or odor). If high chlorine concentrations are found at the outfall (greater than about 0.5 mg/L), then a major treated potable water leak is likely associated with the dry-weather flow.

Table 6 lists the detection limit requirements for the tracer parameter concentrations found during the Birmingham, Alabama, demonstration project. The recommended analytical methods satisfy most of the required detection limits, except for ammonia and surfactants in spring water and surfactants in potable water. The spring water ammonia concentrations were about equal to the detection limit, but because the variation in the ammonia concentrations were so large, a much lower detection limit would be preferable.

Figures 4 through 7 are probability plots showing the required analytical detection limits for mixtures of two source area flows both having low COV values (similar to the majority of expected conditions). Pitt and Lalor (publication pending) present similar plots for all possible combinations of COV values. These figures show four curves corresponding to four mixtures. PER100 is for a 100 percent solution of the flow having the higher tracer concentration, PER50 is for a solution having 50 percent each of two components, PER15 is for a solution of 15 percent of the component having the higher tracer concentration and 85 percent of the component having the lower tracer concentration, while PER0 is a solution only made of the component having the lower tracer concentration. Figure 4 is for two components that have mean concentrations differing by 1.33 times, Figure 5 is for a mixture where the component mean concentrations differ by five times, Figure 6 is for two components with mean concentrations differing by 20 times, and Figure 7 is for two components with mean concentrations differing by 75 times. Each figure shows the detection limits, relative to the lower base concentrations, for different probability of detection values. The detection limits required are reduced significantly as the means of the tracer components differ by greater amounts, especially for low probabilities of detection.

For example, if the two tracer mean concentrations vary by about five times (e.g., treated potable water and sanitary wastewater potassium concentrations from Table 5) and a mixture of 15 percent sanitary wastewater and 85 percent potable water needs to be identified with a 90 percent probability of detection, the required detection limit would be about:

1.4 [factor from Fig.5] x 1.6mg/l [potassium in treated potable water Table 5] = 2.2 mg/L

The more conservative approach stated above would result in a minimum detection limit of:

0.8 [factor for COV < 0.5] x 1.6mg/l = 1.2 mg/L.

TABLE 6. DETECTION LIMIT REQUIREMENTS FOR TRACER CONCENTRATIONS FOUND IN BIRMINGHAM, ALABAMA WATERS

Tracer Parameter and Units	Median Conc. (mg/L) of Least Contaminated Sources: median (COV)	Required Detection Limit	Available Detection limit[1]
Fluorescence % of full scale	Potable water: 4.6 (0.08) Spring water: 6.8 (0.43)	3.7 5.4	0.1
Potassium mg/L	Spring water: 0.73 (0.10) Potable water: 1.6 (0.04)	0.58 1.3	0.01
Ammonia mg/L	Spring water: 0.01 (1.7) Potable and Radiator water: 0.03 (0.23)	0.001 0.024	0.01
Fluoride mg/L	Spring water: 0.031 (0.87) Sanitary wastewater: 0.77 (0.23)	0.01 0.62	0.01
Surfactants mg/L as MBAS	Spring and potable water: <1 Sanitary wastewater: 1.5 (0.82)	- 0.35	0.01
Hardness mg/L as $CaCO_3$	Laundry water: 14 (0.57) Potable and radiator water: 49 (0.03)	3.2 39	1
Color HACH™ color units	Spring and potable water: <1 Sanitary wastewater: 38 (0.55)	- 8.7	1
Specific Conductivity μS/cm	Potable water: 110 (0.01) Spring water: 300 (0.04)	88 240	10

(1) From anlaytical methods discussed under: "Recommended Analytical Methodology".

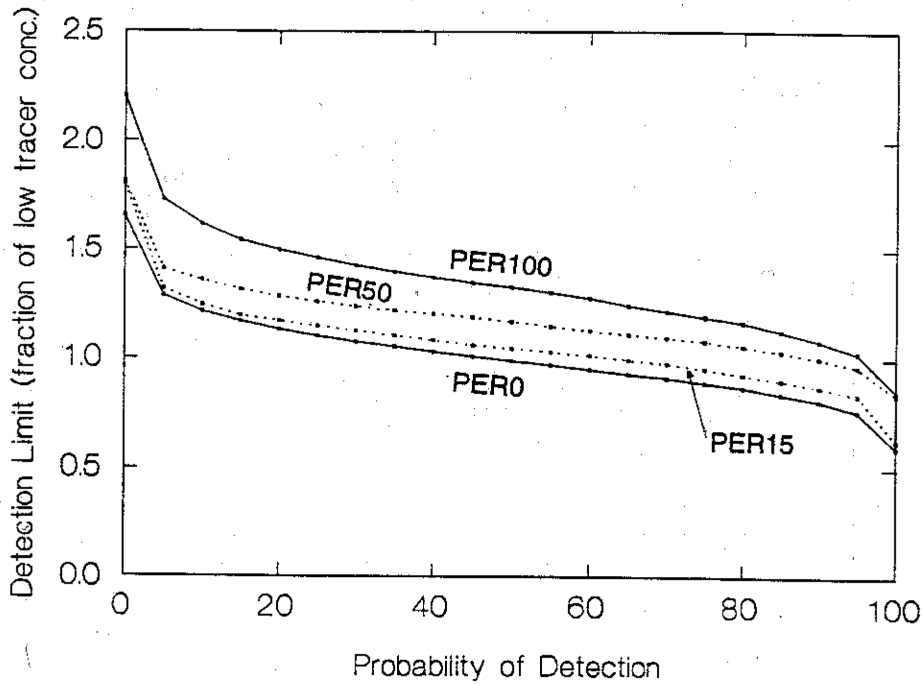

Figure 4. Required detection limits for low COV mixture components having means differing by 1.3 times.

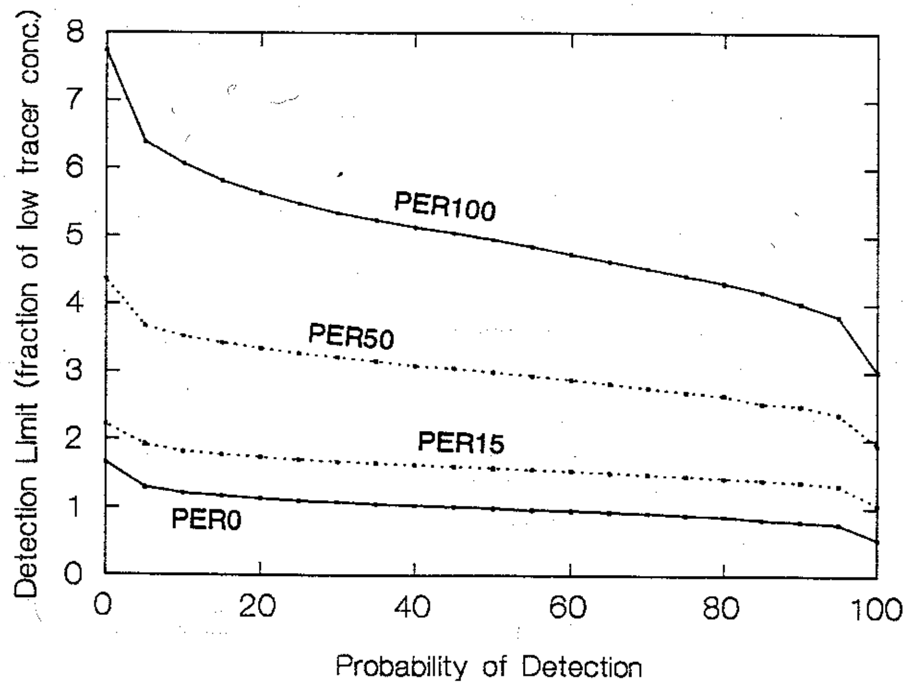

Figure 5. Required detection limits for low COV mixture components having means differing by 5 times.

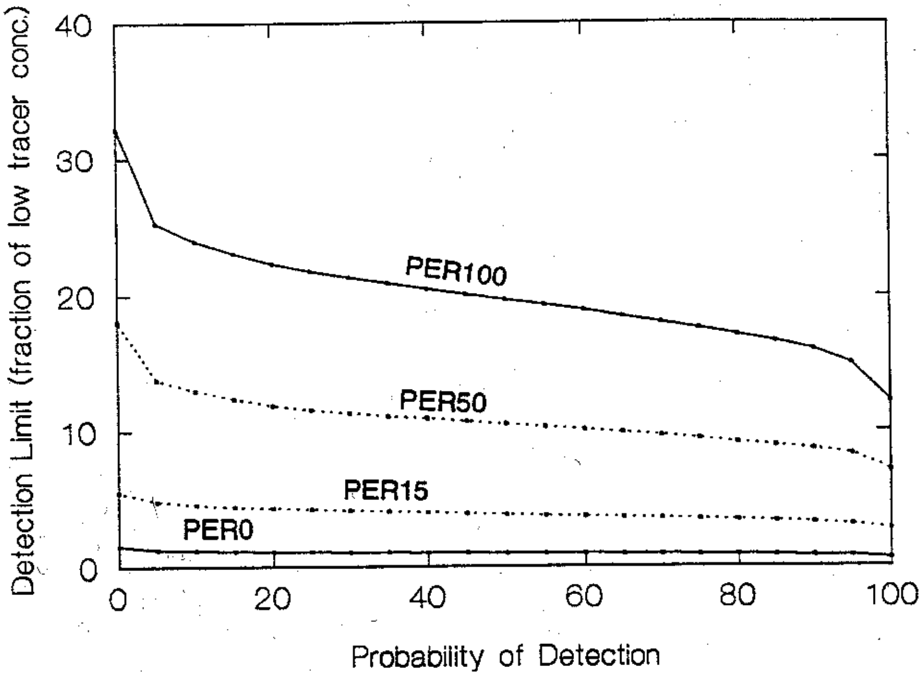

Figure 6. Required detection limits for low COV mixture components having means differing by 20 times.

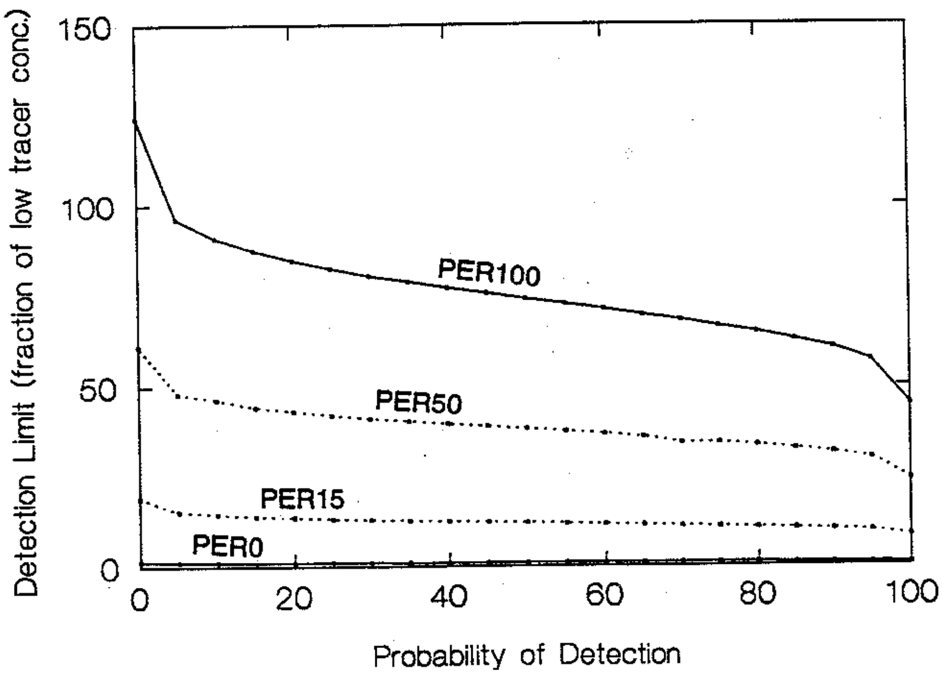

Figure 7. Required detection limits for low COV mixture components having means differing by 75 times.

Even with the above analytical requirements satisfied, it may still be difficult to precisely estimate the degree of contamination, especially for low contamination levels and for high COVs. The ratio of the tracer concentration in the contaminating source flow to the tracer concentration in the cleaner baseflow must increase as the desire to detect smaller contaminating source flows is required. Listed below, for 90 percent confidence levels and low COV values, are percentages of source flow in the baseflow and the corresponding minimum concentration ratios (source to clean baseflow tracer concentrations) required for the detection of the source flow contamination of the baseflow.

Percent of Source Flow Contamination in Baseflow:	Required concentration ratios (low COV values):
1%	50
5%	10
10%	7
25%	3
35%	1.5
50%	1.2

As an example, the median tracer concentration in the contaminating source flow must be about 10 times greater than the median tracer concentration in the cleaner baseflow to detect a five percent source flow contamination of the baseflow. If the tracer COV values are "medium" or "high", then the required concentration differences are much greater (up to 250 times difference in concentrations may be required).

Therefore, the differences in tracer concentrations must be quite large, and the COVs quite small, in order to have confident estimates of low levels (percentages) of contaminating source flows. Few tracers exhibit such a wide range in characteristics between source flow and baseflow categories. This is the main reason why the use of multiple tracers for source flow identification is important. Some tracers may not uniformly produce good estimates of contaminating source flow levels, but the use of redundant tracers for the same decision (e.g., ammonia and potassium to identify sanitary wastewater; fluorides and hardness to identify treated potable water; and surfactants and fluorescence to identify wash waters) and good estimates of local contaminant characteristics, will minimize these errors.

The actual minimum level of contaminating source flow that will be detectable will be dependent on the analytical precision, as discussed next.

Required Sample Analytical Precision

The repeatability of the analytical method is an important consideration in its selection. Precision, as defined in Standard Methods (APHA, et al. 1989), is a measure of the closeness with which multiple analyses of a given sample agree with each other. It is determined by repeated analyses of a stable standard, conducting replicate analyses on the samples, or by analyzing known standard additions to samples. Precision is expressed as the standard deviation of the multiple analysis results.

Figure 8 is a summary of the probability plots from Pitt and Lalor (publication pending) and indicates the needed analytical precision (repeatability) as a fraction of the median tracer concentration (i.e., the flow with the lower tracer concentration) to resolve one percent contamination of the baseflow by the source flow, at a 90 percent confidence level. This figure was developed for COV values of the tracer parameters in the contaminating flows ranging from 0.16 to 1.67.

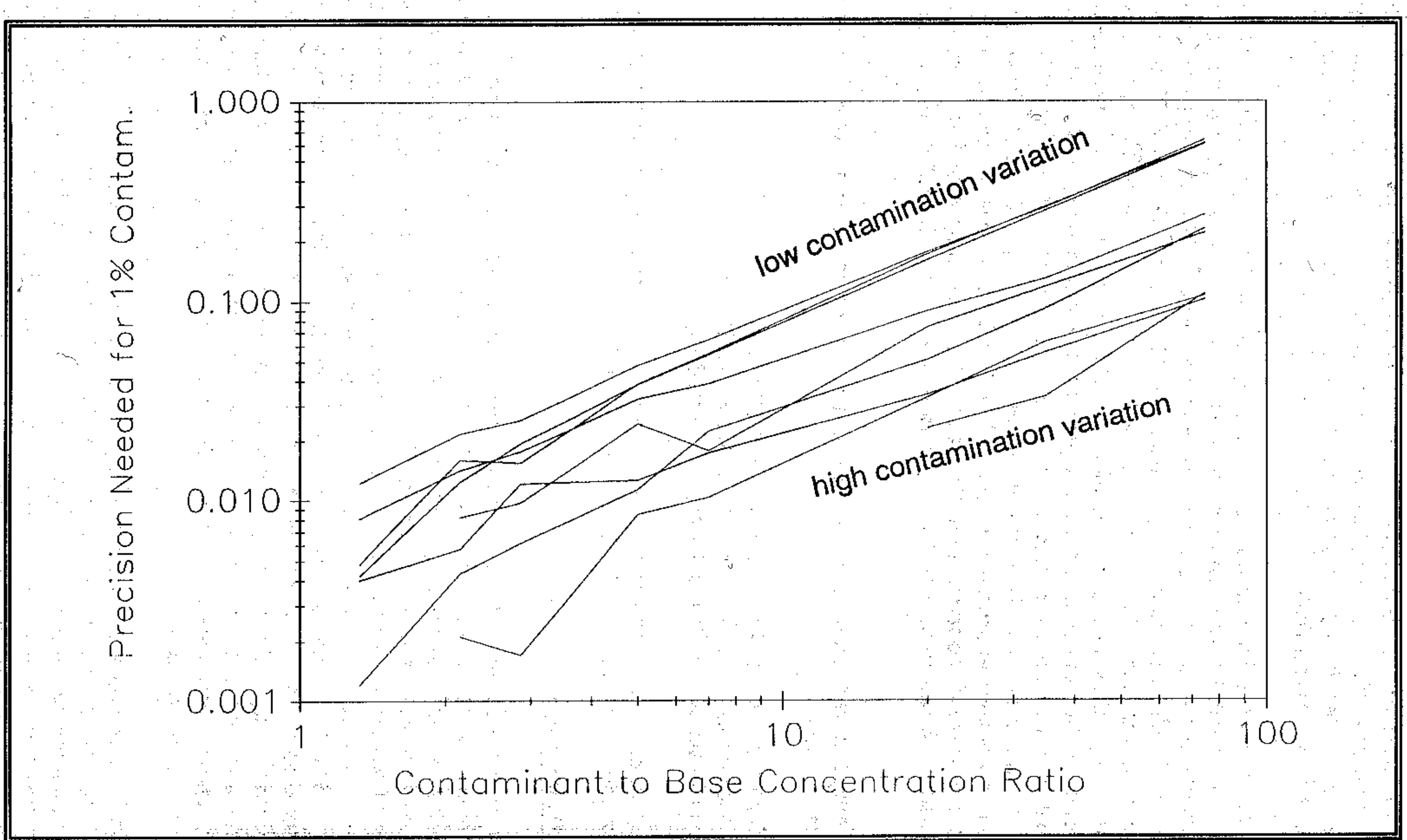

Figure 8. Analysis precision needed for detection of one percent contamination at ninety percent confidence.

If the available analytical precision is worse than these required values, then small contaminating flow levels may not be detected. Therefore, even with adequate analytical detection limits, poor analytical precision may not allow adequate identification of low levels of contaminating flow. In many cases, it is expected that a contaminating flow level of just a few percent can cause significant toxic and pathogenic problems. Examples include gasoline spills, direct connections of raw sanitary wastewater, and metal plating bath wastewaters.

If the tracer concentrations of the flow components are close in value and the variation of the concentrations are high, then it will be very difficult to adequately discern flow components. In contrast, if the tracer concentrations of the flow components are widely different and have low variabilities, then much smaller levels of contaminating flows could be detected. As an example, if the median contaminant tracer concentrations differ by a factor of 10 in two flow components, but have high concentration variations (high COV values), a precision of between 0.015 to 0.03 of the lower baseflow median tracer concentration is needed, for each percent of contaminating flow that needs to be detected. If the median tracer concentration in the cleaner baseflow is 0.15 mg/L (with a corresponding tracer median concentration of 10 times this amount, or 1.5 mg/L, in the contaminating source flow), then the required analytical precision is about 0.015 x 0.15 = 0.002 mg/L to 0.03 x 0.15 = 0.005 mg/L per one percent of contaminating flow to be detected. If at least five percent of contaminating flow is needed to be detected, then the minimum precision would have to be 5 x 0.002 = 0.01 mg/L.

The conservative method noted previously can be used to estimate the detection limit requirements for the above example:

low COV in the cleaner baseflow: 0.8 x 0.15 mg/L = 0.12 mg/L
medium COV in the cleaner baseflow: 0.23 x 0.15 mg/L = 0.035 mg/L
high COV in the cleaner baseflow: 0.12 x 0.15 mg/L = 0.018 mg/L.

The required analytical precision would therefore be about one-half of the lowest detection limit needed, and about 1/12 of the largest estimated required detection limit.

Recommended Analytical Methodology

An important part of the development of these investigation procedures and the demonstration project (Pitt and Lalor publication pending) was the laboratory and field testing of alternative analytical methods. Dry-weather outfall samples were subjected to different tests which compared several analytical methods for each of the major tracer parameters of interest. Tests were conducted to enable comparison of the results of alternative tests with standard procedures and to identify which methods had suitable detection limits, based on real samples. In addition, representative samples were further examined using standard addition methods (known amounts of standards added to the sample and results compared to unaltered samples) in order to identify matrix interferences. Matrix interferences are generally caused by contaminants in the samples interfering with the analysis of interest. Many of the analysis methods were also tested against a series of standard solutions to identify analytical precision (repeatability), linearity, and detection limits. The following paragraphs (and Table 7) summarize the recommended analytical procedures.

Most of the recommended analyses are conducted using small "field-type" instruments. However, despite their portability, the use of these instruments in the field can introduce many errors. Temperature and specific conductivity are the only analyses that are recommended for field analyses. For the other analyses, samples are collected at the site, iced, and taken back to the laboratory for analyses. The recommended analytical procedures can be easily conducted in a temporary laboratory; all that is needed is a work space and adequate ventilation. Access to power and water would be

TABLE 7. SAMPLE ANALYSES LAB SHEET

Sample number:____________________

Date:____________________

Location:____________________

Outfall #:____________________

Specific conductivity YSI™ SCT meter (field)____________________

Temperature YSI™ SCT meter (field)____________________

pH pH meter (lab)____________________

Ammonia Direct Nesslerization (lab)____________________

Color HACH™ color kit (lab)____________________

Fluoride HACH DR/2000™ spect. with AccuVacs™ (lab)__________

Hardness HACH™ field titration kit (lab)____________________

Surfactants HACH™ detergent field kit (lab)____________________

Fluorescence Turner™ fluorometer (lab)____________________

Potassium HACH DR/2000™ spect. (lab)____________________

Turbidity HACH™ Nephelometer (lab)____________________

Chlorine HACH DR/2000™ spect. with AccuVacs™ (lab)__________

Toxicity Microtox™ 100% sample screen (lab)____________________ helpful, but all of the equipment can be operated with batteries. At each outfall, a (2 L) sample of dry-weather discharge needs to be collected and stored in a polyethylene container. Another (500 mL) sample can also be collected in a glass container having a Teflon-lined lid for toxicity screening and selected toxicant analyses. All samples must be analyzed (or extracted) within accepted time limits.

Descriptions of the procedures and parameters recommended for the analysis and identification of dry-weather outfall samples are:

Water color--

Determine in the laboratory using a simple comparative colormetric (color wheel) field test kit from the HACH Company. Apparent color (unfiltered samples), expressed in HACH color units.

pH--

pH is measured in the laboratory using a standard laboratory pH meter after accurate calibration using at least two buffer solutions bracketing the expected sample pH value. (pH measurements using pH test paper have been found to be generally within one unit of the laboratory meter. However, this difference is too large and is not recommended. Small "pen" pH meters most suitable for field use can easily be off by a 0.5 pH unit and are relatively hard to calibrate. They accordingly must be used with care.)

Specific conductivity and temperature--

These parameters are quickly and easily measured in the field using a multi-parameter SCT meter from YSI model 33. Both specific conductivity and temperature must be calibrated against standard specific conductivity solutions and a standard thermometer. Specific conductivity should also be corrected to standard values obtained at 25°C (APHA, et al. 1989):

$$K = (K_m C)/[1 + 0.0191(t-25)]$$

where K = specific conductivity at 25°C

K_m = measured specific conductivity at temperature t°C

and C = cell constant

The cell constant is a correction factor determined by measuring a 0.01M KCl solution at 25°C, after three rinses, compared to 1413 μS/cm, the expected value. This equation results in about a 2% change in specific conductivity for every degree in temperature difference from 25°C. The International System of Units (Systême International d' Unités, SI) specific conductivity unit of measurement is the μS/cm which is numerically equivalent to the U.S. Customary unit, μmhos/cm.

Fluoride--

Easily analyzed in the laboratory using a field spectrophotometer and evacuated reagent and sample vessels (HACH DR/2000™ and AccuVac™ ampules using SPADNS reagent, without distillation). The AccuVac™ procedure works well for sample concentrations less than 2.5 mg/L; however, in rare instances of higher concentrations, sample dilution is required because of non-linear instrument responses. The samples should be filtered through a 0.45 μ membrane filter (e.g., Millipore™ filter) before analysis to minimize color interference. (Specific-ion probes were also evaluated, but the technique proved to be too inconsistent, especially for personnel having little training.)

Ammonia--

Easily measured in the laboratory using a direct Nesslerization procedure and spectrophotometer (HACH DR/2000™ Nessler method, but without sample distillation). The samples should be filtered through a 0.45 μ membrane filter before analysis to minimize color interference. (The use of various indicator test papers and simple field test kits for ammonia determination gave poor results. Specific-ion probes were also tested. Typical problems encountered for these procedures, (except for the direct Nesslerization procedure), were color interferences, long analysis times, inconsistent results, and poor performance when standard solutions were analyzed.)

Potassium--

Measured in the laboratory either using a spectrophotometer (HACH DR/2000™ Tetraphenylborate method), or a flame atomic absorption spectrophotometer (if available). The samples should be filtered through a 0.45 μ membrane filter before spectrophotometric analysis to minimize color interference. (Specific-ion probes were also evaluated and indicated the same poor results found for fluorides and ammonia.)

Surfactants--

Measured in the laboratory using a simple comparative colormetric (color wheel) method (from the HACH Company). The samples should be filtered through a 0.45 μ membrane filter before analysis to minimize color interference. This procedure should be carried out under a laboratory fume hood. (Specific-ion probe titrations for surfactants were not successful because of poor detection limits.)

Fluorescence--

Analyzed using a laboratory fluorometer (Turner model 111). The fluorometer had general purpose filters and lamps and was operated at the most sensitive setting (number one aperture).

Hardness--

Determined in the laboratory using a field-titrimetric kit (HACH Digital Titrator Model 16900). The samples should be filtered through a 0.45 μ membrane filter before analysis to minimize color interference. (A number of simple field test kits were tested but the direct reading titration method proved most convenient and accurate. However, hardness test paper can be used to estimate the titration end point.)

Turbidity--

Determined using a HACH Nephelometer in the laboratory.

Chlorine--

Total available chlorine was determined with the DPD (N, N-diethyl-p-phenylenediamine) method using a HACH DR/2000™ spectrometer with AccuVac™ ampules.

Toxicity-screening--

Toxicity screening tests have been found to be very useful as indicators of contamination of storm drains. The Microtox™ (from Microbics) toxicity screening test can be used for relative toxicity values. The 100 percent screening test was most commonly used. If the light output decrease after 25 minutes (the I_{25} value) was greater than 50 percent, then the standard Microtox test was used to determine the sample dilution required for a 50 percent light decrease (the EC50 value). If a sample results in a large toxic response, then specific toxicant analyses (organics and metals) could be performed to better identify the toxicant source. In general, the Microtox™ screening test was found to be an efficient method for toxicity analysis, particularly for identifying samples requiring further analyses. (A number of simple test kits were used for specific heavy metal analyses, but with very poor results. High-detection limits and interferences make these methods impractical, unless an outfall is grossly contaminated with a concentrated source, such as raw plating bath wastewater.)

SECTION 5

INITIAL FIELD SCREENING SAMPLING ACTIVITIES

SAMPLING STRATEGY

The importance of sampling all outfalls, regardless of size, should be stressed. Figure 9 shows the distribution of outfalls for the Birmingham, Alabama area surveyed for the city's stormwater discharge permit application. The median equivalent diameter of the 566 outfalls that had drainage area estimates available was 36 in. About 20 percent of the outfalls were greater than 60 in. in diameter and about 20 percent were less than 20 in. in diameter. Most of the largest outfalls were actually drainage ditches. There was an average of about 70 acres draining to each outfall, but the drainage areas ranged from much less than one acre to over 1500 acres. About 40 percent of the outfalls were affected by either commercial or industrial land uses and would therefore be considered as critical drainage areas for both dry-weather flows and stormwater runoff.

The Birmingham, Alabama demonstration project that tested this protocol covered a residential and commercial drainage area having approx. 70 outfalls. The median outfall size of the outfalls in this study area was 16 in., and more than 75 percent of the outfalls were less than 36 in. in diameter. Examination of the outfalls during seven separate sampling occasions found that while some of the dry-weather flows occurred intermittently, most were continuous. About 25 percent of the outfalls were found to be consistently flowing during dry weather, with about two-thirds of the flows discharging from pipes that were less than 36 in. in diameter. About five percent of the outfalls exhibited dry-weather flows which were extremely toxic or were raw, undiluted, sanitary wastewater. Each of these contaminated outfalls were 20 in., or less, in diameter. Some of the worst dry-weather flow discharge problems were associated with very small (4 in. diameter) pipes draining automobile service areas adjacent to the receiving water. It was found that small outfalls can contribute significant pollutant loads to receiving waters and should not be neglected if receiving water improvement is a serious goal.

FIELD DATA COLLECTION

Before the field data can be collected, preliminary mapping and land use evaluation work is needed. Section 3 described the preliminary work and the likely data sources for the information that is needed before the field investigations can begin. The most important preliminary information required is:

- outfall locations,
- outfall drainage areas,
- commercial and industrial activities in each drainage area, and
- locations of septic tanks in the individual drainage areas.

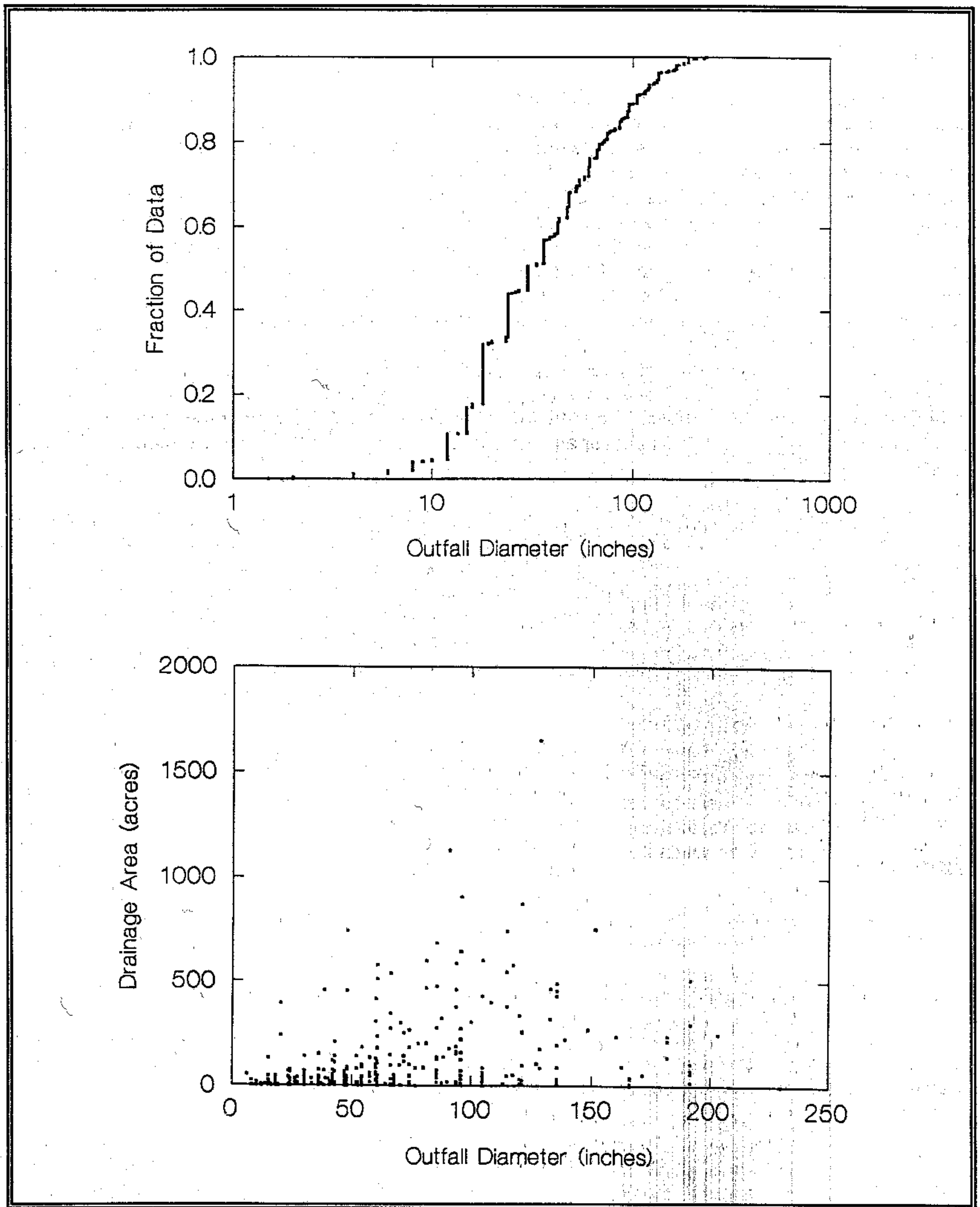

Figure 9. Outfall characteristics for Birmingham, Alabama demonstration project.

Outfall Locations

Frequently, city maps of known outfall locations are inadequate. Many outfalls are not located on city drainage maps because of infrequent or improper updating, or unauthorized installations. Because it is very difficult for communities to maintain up-to-date maps of drainage facilities, actual stream surveys are needed to verify and update existing information. Illicit outfalls will not usually be shown on maps, and field surveys will be required to detect these as well. Most newer developments do have accurate drainage and outfall maps, but the outfall locations may not have been transferred to an overall city map. A few cities have Geographic Information Systems (GIS) in place and are including the storm drainage systems on appropriate data overlays. It is important to identify all outfalls because present data indicates no relationship between the most significant sources of non-stormwater discharges and the largest drainage areas, or the largest diameter outfalls.

Because of the likelihood of poor data concerning the outfall locations, it will probably be necessary to "walk" the creeks and actively look for outfalls. In most cases, it requires several trips (about three) to locate all outfalls. The initial outfall surveys should be conducted during times when riparian vegetation is minimal. Whenever an outfall is located, it needs to be marked (coded using spray paint or by other means).

If the receiving water is a small creek, it can be waded in a downstream direction. If the receiving water body cannot be waded, a small boat or canoe can be used to look for outfalls above the water. Submerged outfalls are more difficult to find and require more careful inspections for storm drain manholes along the shore. In flood or estuary tidal areas, surveys should be conducted during low tides when more outfalls are likely to be exposed. In many cities, streets parallel the banks of creeks or drainage canals that contain outfalls. It may be possible to carefully search the opposite bank from a moving automobile. It may also be cost-effective to use light aircraft (including helicopters) to search for outfalls. Submerged outfalls could be easier to identify from the air than from the water in cases where discharge plumes are visible.

Obviously, outfall characterizations should be conducted during these surveys, if possible. In all cases, at least two people are needed to look for outfalls, especially if wading a creek. Another person can drive a shuttle car to a convenient downstream location for crew rotation.

Field Survey

The main elements of the field sampling plan are the collection of necessary information and equipment, and preliminary screening of outfalls.

Collect necessary information and equipment--

Maps--Maps are the most important part of the field equipment. Adequate field maps can be prepared by enlarging standard USGS 7-1/2 minute quadrangle maps to appropriate scales. In addition, detailed street maps are also needed to locate specific street crossings and to identify locations of outfalls in the field.

Field sampling and analysis equipment--Table 8 lists the equipment that is needed for a field survey. In no case should personnel conduct the field surveys alone, wade streams without wearing waders, or be in boats without wearing life preservers. Heavy duty waders (heavy Cordura™ nylon) are preferred. Urban streams contain appreciable debris (broken bottles, etc.). In addition, urban

TABLE 8. FIELD EQUIPMENT LIST

Temperature and specific conductivity meter.

Field notebook containing maps and non-stormwater flow evaluation field sheets.

Waterproof marker/pen.

Camera and film.

Spray paint.

Tape measures (both 3m and 30m).

Flashlight.

Watch (with second hand).

Glass sample containers with waterproof labels (500 mL).

Plastic sample containers with waterproof labels (1 to 2 L.).

Ice boxes with ice (left in vehicle).

Backpack.

Grab water sampler (dipper on long pole).

Hand operated vacuum pump sampler for shallow flows.

Waders and walking stick.

First aid kit and pocket knife.

Self protection pepper spray.

Two-way radios for communication between field crew and van driver.

Hand held GPS (global positioning satellite) system receiver (only capable of locating positions within about 100 to 350 feet).

streams are isolated wildlife areas which tend to concentrate certain wildlife species that live in close proximity to man (including cottonmouths, water moccasins, copperheads, and rattlesnakes), plus contain lush growths of poison ivy or oak. The self protection pepper spray may be especially handy in case of harassing dogs.

This equipment would supplement needed boating equipment, if boats are used. Some of this equipment (ice coolers and ice, along with extra bottles) would be kept in the vehicle. In most cases, the vehicle should be moved in about 1/2 mile increments. This length would typically contain up to ten outfalls, with relatively few flowing outfalls to sample. The collected samples would therefore be iced within about 1/2 hour of collection. It is possible that the vehicle driver could conduct critical analyses (chlorine, pH and ammonia) while waiting. It is suggested that a three person crew rotate, with a new driver at each new shuttle location.

Arrange for lab testing and other support equipment--Before the field crew goes into the field to collect samples, the laboratory needs to be notified and ready to analyze the samples soon after they are available. As shown in the next section, the laboratory testing procedures for the basic tracer parameters are all simple and can be conducted in an unsophisticated laboratory. It may be feasible for the field crew to conduct the sample analyses in the afternoon of the day when they are collected.

Preliminary screening of outfalls--

Location of outfalls--Outfall locations need to be transferred to field maps and the daily activities planned. The number of outfalls that can be visited and sampled in a single day is highly dependent on outfall accessibility and mobility along the receiving water. The initial survey requires the longest time, after which repeated surveys require much less effort. In a small creek having shallow and slow water with numerous road crossings, about three miles of creek can be walked (with about 40 outfalls visited and ten outfall samples obtained) in a half-day of field activity with a crew of three people. Most other conditions would require additional labor for the same sampling effort. In all cases, careful planning, especially having an idea of where the outfalls are located, would greatly reduce the labor involved.

Scheduling field surveys--It is important to schedule the field surveys during low water levels (during low tides or low flows) because outfalls could be submerged and concealed during high water conditions. It is also best not to conduct the field surveys during periods of high flow in the receiving waters because of safety concerns.

Field surveys which are timed (diurnally, or seasonally) to coincide with periods with a greater potential for non-stormwater entries, are likely to reveal more dry-weather discharges. As examples, morning periods (or in areas of tourism, during the tourist season) usually experience the greatest sanitary wastewater flows. Scheduling sampling during these morning hours would be most successful in identifying sanitary wastewater contamination of the storm drainage system. Many inappropriate industrial entries to the storm drainage system also occur on a scheduled basis, e.g., cleaning up work areas between work shifts, or increased wastewater flows during periods of the year when the specific industry is especially busy. Again, investigating potentially affected storm drain outfalls during these critical periods would result in better data.

The field survey schedule will need to be flexible to avoid sampling during and immediately after a storm event, to ensure only dry-weather flows are recorded. In most urban areas storm runoff drainage flows will cease within 12 hours following the storm event, but this will need to be reviewed for each watershed area. The time to flow through the upstream drainage system and any detention and subsequent release of the storm water could extend this 12 hour period. This subject is discussed further under Section 5, Irregular Flows.

Sampling techniques--After an outfall is located, it is labeled with paint or marked by other means and the form shown on Table 9 is completed in the field. Table 10 describes the physical observation choices, previously discussed in Section 4. The use of field sheets and laboratory record keeping is very important because of the large number of outfalls that will likely be surveyed in each municipality.

Table 9 is a field sheet that can be used to record the observations and analytical results for the outfall survey. The top of the sheet includes basic outfall descriptive and weather information, a flow rate estimate, and an indication if industrial or commercial activities are known to occur in the area. The physical observation data section requires simple circling of the most appropriate value, or writing in another response. Samples should be obtained of floatable and staining materials for further laboratory microscopic analyses. If unusual vegetative conditions or damage to structures are found, then the extent and appearance of the damage should be described. In all cases, several photographs need to be taken of outfall conditions for each site visit. The analyses results are written on the form, along with a short descriptions of the equipment used.

Flows are estimated and visually characterized for each outfall visit. Field temperature and specific conductivity measurements are made in the field, and dry-weather discharge water samples are collected for later (same day) laboratory analyses. A single water sample (1 to 2 L) is sufficient for almost all analyses that may be conducted on the sample. This sample can be collected in a polyethylene collapsible container. In addition, another (500 mL) sample can be collected in a glass bottle (having a Teflon lined lid) if a toxicity screening procedure (like Microtox™) and selected organic tracers are to be analyzed. Specific sample volume requirements need to be determined in conjunction with the laboratory personnel. Excess samples should be placed in smaller polyethylene bottles and frozen for potential future analyses (e.g., heavy metals and major ions).

Sample preservation--Usually icing of samples after collection and same-day laboratory analyses is adequate. Ammonia, chlorine, and pH are susceptible to change with time and special tests may be needed to determine the tolerable delay before laboratory analyses. As noted previously, it is not efficient to analyze the samples in the field, especially after each sample is collected.

Field tests--The only tests recommended for field analyses are temperature and specific conductivity. If a multi-purpose temperature/specific conductivity meter is being used for the temperature analyses, then both can be easily determined in the field.

Record keeping, sample preservation, and analyses--As noted above, the collected water samples need to be analyzed soon after collection. A central laboratory is much more effective than trying to analyze each sample in the field as it is collected. Section 4 presents the recommended laboratory procedures.

Data analyses--

Identification of contaminated outfalls--Section 6 describes several methods to identify the likely components in each flowing outfall. This information is then used to identify the contaminated dry-weather flows.

Isolation and correction of contaminating flow sources--After the problem outfalls are identified, drainage system surveys are used to find the sources of the contaminating flows. These procedures are briefly discussed later in this User's Guide.

TABLE 9. SAMPLE EVALUATION SHEET

Outfall # _______ Photograph # _______ Date: _____________

Location: ____

Weather: air temp.: ___ °C rain: Y N sunny cloudy

Outfall flow rate estimate: ____ L/sec

Known industrial or commercial uses in drainage area? Y N
describe: ____

PHYSICAL OBSERVATIONS:

Odor: none sewage sulfide oil gas rancid-sour other:_____

Color: none yellow brown green red gray other:______

Turbidity: none cloudy opaque

Floatables: none petroleum sheen sewage other:______ (collect sample)

Deposits/stains: none sediment oily describe:________ (collect sample)

Vegetation conditions: normal excessive growth inhibited growth
extent: ____

Damage to outfall structures:
identify structure: _________________________________
damage: none / concrete cracking / concrete spalling / peeling paint / metal corrosion
other damage: ____________________________________
extent: ____

ANALYSES:		EQUIPMENT USED:
Specific conductivity:	___ μS/cm	________________
Temperature:	___ °C	________________
Fluoride:	___ mg/L	________________
Hardness:	___ mg/L	________________
Surfactants:	___ mg/L	________________
Florescence:	___ % of scale	________________
Potassium:	___ mg/L	________________
Ammonia:	___ mg/L as N	________________
pH:	___	________________

TABLE 10. INTERPRETATIONS OF PHYSICAL OBSERVATION PARAMETERS AND LIKELY ASSOCIATED FLOW SOURCES

Odor - Most strong odors, especially gasoline, oils, and solvents, are likely associated with high responses to the toxicity screening test. Typical obvious odors include: gasoline, oil, sanitary wastewater, industrial chemicals, decomposing organic wastes, etc.

sewage: smell associated with stale sanitary wastewater, especially in pools near outfall.
sulfide ("rotten eggs"): industries, e.g., meat packers, canneries, dairies, etc; and stale sanitary wastewater.
oil and gas: petroleum refineries or facilities associated with vehicle maintenance and operation or petroleum product storage.
rancid-sour: food preparation facilities (restaurants, hotels, etc.).

Color - Important indicator of inappropriate industrial sources. Industrial dry-weather discharges may be of various colors, but dark colors, such as brown, gray, or black, are most common.

yellow: chemical, textile, and tanning plants.
brown: meat packers, printing plants, metal works, stone and concrete works, fertilizer application, and petroleum refining facilities.
green: chemical plants, and textile facilities.
red: meat packers.
gray: dairies.

Turbidity - Often affected by the degree of gross contamination. Dry-weather industrial flows with moderate turbidity can be cloudy, while highly turbid flows can be opaque. High turbidity is often a characteristic of undiluted dry-weather industrial discharges.

cloudy: sanitary wastewater, concrete or stone operations, fertilizer facilities, and automotive dealers.
opaque: food processors, lumber mills, metal operations, and pigment plants.

Floatable Matter - A contaminated flow may contain floating solids or liquids directly related to industrial or sanitary wastewater pollution. Floatables of industrial origin may include animal fats, spoiled food, oils, solvents, sawdust, foams, packing materials, or fuel.

oil sheen: petroleum refineries or storage facilities and vehicle service facilities.
sewage: sanitary wastewater.

(continued)

TABLE 10. (continued)

Deposits and Stains - Refer to any type of coating near the outfall and are usually of a dark color. Deposits and stains often will contain fragments of floatable substances. These situations are illustrated by the grayish-black deposits that contain fragments of animal flesh and hair which often are produced by leather tanneries, or the white crystalline powder which commonly coats outfalls due to nitrogenous fertilizer wastes.

sediment: construction site erosion.
oily: petroleum refineries or storage facilities and vehicle service facilities.

Vegetation - Vegetation surrounding an outfall may show the effects of industrial pollutants. Decaying organic materials coming from various food product wastes would cause an increase in plant life, while the discharge of chemical dyes and inorganic pigments from textile mills could noticeably decrease vegetation. It is important not to confuse the adverse scouring effects of high stormwater flows on vegetation with highly toxic dry-weather intermittent flows.

excessive growth: food product facilities.
inhibited growth: high stormwater flows, beverage facilities, printing plants, metal product facilities, drug manufacturing, petroleum facilities, vehicle service facilities and automobile dealers.

Damage to Outfall Structures - Another readily visible indication of industrial contamination. Cracking, deterioration, and spalling of concrete or peeling of surface paint, occurring at an outfall are usually caused by severely contaminated discharges, usually of industrial origin. These contaminants are usually very acidic or basic in nature. Primary metal industries have a strong potential for causing outfall structural damage because their batch dumps are highly acidic. Poor construction, hydraulic scour, and old age may also adversely affect the condition of the outfall structure which are not indications of upstream contaminating entries.

concrete cracking: industrial flows
concrete spalling: industrial flows
peeling paint: industrial flows
metal corrosion: industrial flows

Irregular Flows

Irregular flows pose a special problem during the field surveys. Outfall apparent "dry-weather" flows can be intermittent in nature, only flowing soon after rains and then remaining dry, or may flow when inappropriate water sources enter the storm drainage system. If irregular flows are associated with rains, outfall surveys should be postponed until sufficient time has lapsed since the last major rain. For most urban areas, storm runoff drainage ends several hours (but usually less than 12) after the rain stops. Extended, but decreasing flows, after rains could be associated with high groundwater or percolating rain water infiltrating into the drainage system. In this case, most outfall surveys should be further delayed. However, some pollutant sources may be associated with these after storm flows, especially contaminated groundwaters (septic tank problems, leaky underground storage tanks, etc.). Therefore, it may be important to sample these flows, especially if these contaminant sources potentially exist.

Basic field indicators, such as the presence of residual stains or deposits, oil sheens, coarse solids, floatables, color, odors, etc., in the absence of a flow, indicate the likelihood of intermittent dry-weather flows. These observations will be enhanced by installing simple "tell-tale" devices, e.g., a terry-cloth (strain the discharge) or small caulk dam in the drain. Outfalls exhibiting these signs of non-continuous discharges should be visited several times to increase the probability of observing and sampling a dry-weather discharge. Analyzing pooled water immediately below the outfall or collected between visits in small, constructed dams within the storm drain can greatly assist in identifying non-continuous discharges. Coarse solids and/or floatables can be captured through the erection of coarse screens and/or booms at a manhole site, the mouth of the outfall, or in the receiving stream. It may be necessary to visit suspect outfalls frequently. However, it is virtually impossible to capture an isolated short-term intermittent flow (e.g., from the illegal dumping of wastes into the storm drainage system) from outfall visits.

Simple outfall area characteristics, noted above, are the most reliable indicator of a potential intermittent source at an outfall. In addition to using a dam, or other indicator device (e.g., a small screen to capture particulate debris), it may be desirable to use an automatic water sampler at especially important outfalls. Automatic samplers would be unreasonable and expensive to use at many outfalls in an area and test locations would need to be carefully selected. A sampler located in a close-by manhole and set to sample every fifteen minutes (with four samples placed in each bottle) can monitor for intermittent flows for a period of 24 hours. Automatic samplers can also be used to characterize variable quality flows. This information can be valuable in identifying possible discharge sources.

SECTION 6

DATA ANALYSIS TO IDENTIFY PROBLEM OUTFALLS AND FLOW COMPONENTS

The field screening surveys are to be used as an initial effort to identify the outfalls needing more detailed drainage area investigations which would identify specific pollutant sources and control options. These field screening surveys, discussed in Sections 4 and 5, include physical, chemical, and relative toxicity evaluations of outfall and/or discharge conditions.

The purpose of the procedures presented in this User's Guide is to separate storm drain outfalls into general categories (with a known level of confidence) and to identify which outfalls (and drainage areas) need further analyses and investigations. The categories used in this Guide are outfalls affected by non-stormwater entries from: (1) pathogenic or toxic pollutant sources, (2) nuisance and aquatic life threatening pollutant sources, and (3) unpolluted water sources.

The pathogenic and toxic pollutant source category should be considered the most severe because it could cause disease upon water contact or consumption and cause significant impacts on receiving water organisms. They may also cause significant water treatment problems for downstream consumers, especially if they contain soluble metal and organic toxicants. These pollutants may originate from sanitary, commercial, and industrial wastewater non-stormwater entries. Other important residential area activities that may also be considered in this most critical category (in addition to sanitary wastewater) include inappropriate household toxicant disposal, automobile engine de-greasing, vehicle accident clean-up, and irrigation runoff from landscaped areas excessively treated with chemicals (fertilizers and pesticides).

Nuisance and aquatic life threatening pollutant sources can originate from residential areas and can include laundry wastewater, landscaped area irrigation runoff, automobile washing, construction site dewatering, and washing of concrete mixing trucks. These pollutants can cause excessive algal growths, depressed dissolved oxygen concentrations, tastes and odors in downstream water supplies, offensive coarse solids and floatables, and highly colored, turbid or odorous waters.

Relatively clean or unpolluted water discharged through stormwater outfalls can originate from natural springs feeding urban creeks that have been converted to storm drains, infiltrating groundwater, and infiltrating potable water from water line leaks.

A method must be used to compare data from individual outfall dry-weather samples to the library of dry-weather source flow data to identify which outfalls belong in which general category of contamination listed above. This comparison should result, at the very least, in the identification of the outfalls that are considered as major pollutant sources for immediate remediation. The degree of detail which can be identified for an outfall will depend on the extent of the local data collected to describe the likely source flows.

The procedures that can be used to identify outfall flow components may begin with simple yes/no checks. For example, if no surfactants are measured in an outfall sample, then sanitary wastewater is unlikely to be a contributor to the outfall flow. If no fluoride is measured, then fluoride treated potable water sources could be ruled out as contributors. The probability that remaining contenders are present alone or in a mixture may be determined using a combination of matrix algebra and the selecting of random values from within specified ranges using a Monte Carlo process and many iterations.

Most contaminated outfalls will require correction before the receiving water quality recovers to acceptable levels. However, ranking the outfalls allows the most serious outfalls to be recognized and enables corrective action to be initially concentrated in the most cost-effective manner. In some of the case studies investigated, correcting only problems at the most critical outfalls resulted in insufficient receiving water quality improvements. It may be important to eventually correct all non-stormwater discharge problems throughout a city, not just the most severe problems. The field screening program should therefore be considered as an initial effort that needs to be followed-up with more detailed watershed drainage surveys in most of the areas having observed dry-weather flows. The follow-up watershed surveys are to identify and correct inappropriate pollutant entries into storm drainage systems, as discussed in Sections 7 and 8.

The identification of flow components of the dry-weather storm drain flow can be used to determine which outfalls have the greatest pollution potential. As an example, if an outfall contains sanitary wastewater, it could be a significant source of pathogenic microorganisms. Similarly, if an outfall contains plating bath water from a metal finisher, it could be a significant source of toxicants. These outfalls would be grouped into the most critical category of toxicants/pathogens. If an outfall contains washwaters from a commercial laundry or car wash, the wastewater could be a major source of nutrients and foaming material. These outfalls would be grouped into an intermediate category of nuisance and aquatic life threatening. Finally, if an outfall only contains unpolluted groundwater or water from leaky potable water mains, the water would be non-polluting and the outfall would be grouped into the last category of unpolluted water sources.

The five methods of data analyses presented in the following discussions present a hierarchy of methods, ranging from relatively simple reviews of the outfall characteristics to more sophisticated methods requiring computer modeling for evaluation. It is suggested that as many of the procedures be used as possible in evaluating the data, as each method provides some unique insights into the problems. Pitt and Lalor (publication pending) contains a more through discussion of these analysis procedures, including evaluation of the Birmingham, Alabama, demonstration project data.

INDICATORS OF CONTAMINATION

Indicators of contamination (negative indicators) are clearly apparent visual or physical parameters indicating obvious problems and are readily observable at the outfall during the field screening activities. These observations are very important during the field survey because they are the simplest method of identifying grossly contaminated dry-weather outfall flows. The direct examination of outfall characteristics for unusual conditions of flow, odor, color, turbidity, floatables, deposits/stains, vegetation conditions, and damage to drainage structures is therefore an important part of these investigations. Table 10 in Section 5 presented a summary of these indicators, along with narratives of the descriptors to be selected in the field.

This method does not allow quantifiable estimates of the flow components and if used alone will likely result in many incorrect determinations (missing outfalls that have important levels of contamination). These simple characteristics, discussed further below, are most useful for identifying gross contamination. Only the most significant outfalls and drainage areas would therefore be recognized from this method. The other methods, requiring chemical determinations, can be used to quantify the flow contributions and to identify the less obviously contaminated outfalls.

Indications of intermittent flows (especially stains or damage to the structure of the outfall) could indicate serious illegal toxic pollutant entries into the storm drainage system that will be very difficult to detect and correct. Highly irregular dry-weather outfall flow rates or chemical characteristics could indicate industrial or commercial inappropriate entries into the storm drain system.

During the demonstration phase of this research project (Pitt and Lalor publication pending), odors and high turbidity were found to be the most useful physical indicators of severely contaminated outfall flows. High turbidity correlated well with high levels of surfactants and toxicity. Noticeable odors also correlated well with elevated toxicity. Color was not a very useful indicator of gross contamination and elevated toxicity, unless the color exceed 65 HACH color units.

Gross industrial wastewater contamination may be indicated by the presence and nature of floatable material and deposits near the outfall. Table 11 summarizes possible chemical and physical characteristics of non-stormwater discharges which could come from various industries. The properties considered are pH, total dissolved solids, odor, color, turbidity, floatable materials, vegetation, and damage to outfall structure. The descriptions in each of these categories contain the most likely conditions for a non-stormwater discharge coming from a particular industry. It should be noted that outfalls are likely to be affected by several industrial sources simultaneously, especially if draining industrial parks. The initial watershed analysis, discussed previously, which needs to describe the industrial and commercial facilities that are operating in each outfall's watershed, will be of great assistance in identifying which industries may be contributing dry-weather entries into the storm drainage system.

SIMPLE CHECKLIST FOR MAJOR FLOW COMPONENT IDENTIFICATION

Figure 10 is a flow chart describing the analysis strategy to identify the major non-stormwater discharge sources in residential areas. The first indicator is the presence or absence of flow. If no dry-weather flow exists at an outfall, then indications of intermittent flows must be investigated. Specifically, stains, deposits, odors, unusual stream-side vegetation conditions, and damage to outfall structures can all indicate intermittent non-stormwater flows. However, frequent visits to outfalls over long time periods are needed to confirm that only stormwater flows occur. The other points on the flow chart (Figure 10) serve to indicate if major contaminating sources are present, or if the water is uncontaminated water. The other methods discussed later are needed to quantify the component contributions.

Treated Potable Water

A number of tracer parameters may be useful for distinguishing treated potable water from natural waters:

- Major ions or other chemical/physical characteristics of the flow components can vary substantially depending upon whether the water supply sources are groundwater or surface water, and whether the sources are treated or not. Specific conductance may also serve as a rough indicator of the major water source.

- Fluoride can often be used to separate treated potable water from untreated water sources. Untreated water sources can include local springs, groundwater, regional surface flows or non-potable industrial waters. If the treated water has no fluoride added, or if the natural water has fluoride concentrations close to potable water fluoride concentrations, then fluoride may

TABLE 11. CHEMICAL AND PHYSICAL PROPERTIES OF INDUSTRIAL NON-STORMWATER ENTRIES INTO STORM DRAINAGE SYSTEMS

SIC Group Numbers	Industrial Categories Major Classifications	Odor	Color	Turbidity	Floatables	Debris & Stains	Damage to Outfall Structures	Vegetation	pH	Total Dissolved Solids
Primary Industries										
20	*Food and Kindred Products*									
201	Meat Products	Spoiled Meats Rotten Eggs and Flesh	Brown to Reddish Brown	High	Animal Fats, Byproducts Pieces of Processed Meats	Brown to Black	High	Flourish	Normal	High
202	Dairy Products	Spoiled Milk Rancid Butter	Gray to White	High	Animal Fats Spoiled Milk Products	Gray to Light Brown	High	Flourish	Acidic	High
203	Canned & Preserved Fruits & Vegetables	Decaying Products Compost Pile	Various	High	Vegetable Waxes, Seeds, Skins, Cores, Leaves	Brown	Low	Normal	Wide Range	High
204	Grain Mill Products	Slightly Sweet & Musty Grainy	Brown to Reddish Brown	High	Grain Hulls and Skins Straw & Plant Fragments	Light Brown	Low	Normal	Normal	High
205	Bakery Products	Sweet and or Spoiled	Brown to Black	High	Cooking Oils, Lard, Flour, Sugar	Gray to Light Brown	Low	Normal	Normal	High
206	Sugar and Confectionery Products	NA	NA	Low	Low Potential	White Crystals	Low	Normal	Normal	High
207	Fats and Oils	Spoiled Meats, Lard or Grease	Brown to Black	High	Animal Fats, Lard	Gray to Light Brown	Low	Normal	Normal	High
208	Beverages	Flat Soda, Beer or Wine, Alcohol, Yeast	Various	Moderate	Grains & Hops, Broken Glass, Discarded Canning Items	Light Brown	High	Inhibited	Wide Range	High
21	Tobacco Manufactures	Dried Tobacco, Cigars, Cigarettes	Brown to Black	Low	Tobacco Stems & Leaves Papers and Fillers	Brown	Low	Normal	Normal	Low
22	Textile Mill Products	Wet Burlap, Bleach, Soap, Detergents	Various	High	Fibers, Oils, Grease	Gray to Black	Low	Inhibited	Basic	High
23	Apparel and Other Finished Products	NA	Various	Low	Some Fabric Particles	NA	Low	Normal	Normal	Low
Material Manufacture										
24	Lumber & Wood Products	NA	NA	Low	Some Sawdust	Light Brown	Low	Normal	Normal	Low
25	Furniture & Fixtures	Various	Various	Low	Some Sawdust, Solvents	Light Brown	Low	Normal	Normal	Low
26	Paper & Allied Products	Bleach, Various Chemicals	Various	Moderate	Sawdust, Pulp Paper Waxes, Oils	Light Brown	Low	Normal	Wide Range	Low
27	Printing, Publishing, and Allied Industries	Ink, Solvents	Brown to Black	Moderate	Paper Dust, Solvents	Gray to Light Brown	Low	Inhibited	Normal	High
31	Leather & Leather Products	Leather, Bleach Rotten Eggs or Flesh	Various	High	Animal Flesh & Hair Oils & Grease	Gray to Black Salt Crystals	High	Highly Inhibited	Wide Range	High
33	Primary Metal Industries	Various	Brown to Black	Moderate	Ore, Coke, Limestone Millscale, Oils	Gray to Black	High	Inhibited	Acidic	High
34	Fabricated Metal Products	Detergents, Rotten Eggs	Brown to Black	High	Dirt, Grease, Oils Sand, Clay Dust	Gray to Black	Low	Inhibited	Wide Range	High
32	Stone, Clay, Glass, and Concrete Products	Wet Clay, Mud Detergents	Brown to Reddish-Brown	Moderate	Glass Particles Dust from Clay or Stone	Gray to Light Brown	Low	Normal	Basic	Low

(continued)

TABLE 11. (continued)

SIC	Industrial Categories Major Classifications SIC Group Numbers	Odor	Color	Turbidity	Floatables	Debris & Stains	Damage to Outfall Structures	Vegetation	pH	Total Dissolved Solids
	Chemical Manufacture									
28	*Chemicals & Allied Products*									
2812	Alkalis and Chlorine	Strong Halogen or Chlorine Pungent, Burning	Alkalis - NA Chlorine - Yellow to Green	Moderate	Glass Particles Dust from Clay or Stone	Gray to Light Brown	Highly Inhibited	Normal	Basic	Low
2816	Inorganic Pigments	NA	Various	High	Low Potential	Various	Low	Highly Inhibited	Wide Range	High
282	Plastic Materials and Synthetics	Pungent, Fishy	Various	High	Plastic Fragments, Pieces of Synthetic Products	Various	Low	Inhibited	Wide Range	High
283	Drugs	NA	Various	High	Gelatin Byproducts for Capsulating Drugs	Various	Low	Highly Inhibited	Normal	High
284	Soap, Detergents, & Cleaning Preparations	Sweet or Flowery	Various	High	Oils, Grease	Gray to Black	Low	Inhibited	Basic	High
285	Paints, Varnishes, Lacquers, Enamels and Allied Products (SB-Solvent Base)	Latex- Ammonia SB-Dependent upon Solvent (Paint Thinner, Mineral Spirits)	Various	High	Latex - NA SB-All Solvents	Gray to Black	Low	Inhibited	Latex-Basic SB-Normal	High
286	*Industrial Organic Chemicals*									
2861	Gum and Wood Chemicals	Pine Spirits	Brown to Black	High	Rosins and Pine Tars	Gray to Black	Low	Inhibited	Acidic	High
2865	Cyclic Crudes, & Cyclic Intermediates, Dyes, & Organic Pigments	Sweet Organic Smell	NA	Low	Translucent Sheen	NA	Low	Highly Inhibited	Normal	Low
287	*Agricultural Chemicals*									
2873	Nitrogenous Fertilizers	NA	NA	Low	NA	White Crystalline Powder	High	Inhibited	Acidic	High
2874	Phosphatic Fertilizers	Pungent Sweet	Milky White	High	NA	White Emorphous Powder	High	Inhibited	Acidic	High
2875	Fertilizers, Mixing Only	Various	Brown to Black	High	Pelletized Fertilizers	Brown Emorphous Powder	Low	Normal	Normal	High
29	*Petroleux Refining and Related Industries*									
291	Petroleum Refining	Rotten Eggs Kerosene, Gasoline	Brown to Black	High	Any Crude or Processed Fuel	Black Salt Crystals	Low	Inhibited	Wide Range	High
30	Rubber & Miscellaneous Plastic Products	Rotten Eggs Chlorine, Peroxide	Brown to Black	Moderate	Shredded Rubber Pieces of Fabric or Metal	Gray to Black	Low	Inhibited	Wide Range	High

(continued)

TABLE 11. (continued)

Industrial Categories Major Classifications SIC Group Numbers	Odor	Color	Turbidity	Floatables	Debris & Stains	Damage to Outfall Structures	Vegetation	pH	Total Dissolved Solids
Transportation & Construction									
15 Building Construction	Various	Brown to Black	High	Oils, Grease, Fuels	Gray to Black	Low	Normal	Normal	High
16 Heavy Construction	Various	Brown to Black	High	Oils, Grease, Fuels Diluted Asphalt or Cement	Gray to Black	Low	Normal	Normal	High
Retail									
52 Building Materials, Hardware, Garden Supply, and Mobile Home Dealers	NA	Brown to Black	Low	Some Seeds, Plant Parts, Dirt, Sawdust, or Oil	Light Brown	Low	Normal	Normal	Low
53 Gen. Merchandise Stores	NA	NA	NA	NA	NA	Low	Normal	Normal	Low
54 Food Stores	Spoiled Produce Rancid, Sour	Various	Low	Fragments of Food Decaying Produce	Light Brown	Low	Flourish	Normal	Low
55 Automotive Dealers & Gasoline Service Stations	Oil or Gasoline	Brown to Black	Moderate	Oil or Gasoline	Brown	Low	Inhibited	Normal	Low
56 Apparel & Accessory Stores	NA	NA	Low	NA	NA	Low	Normal	Normal	Low
57 Home Furniture, Furnishings, & Equipment Stores	NA	NA	Low	NA	NA	Low	Normal	Normal	Low
58 Eating & Drinking Places	Spoiled Foods Oil & Grease	Brown to Black	Low	Spoiled or Leftover Foods	Brown	Low	Normal	Normal	Low
Coal Steam Electric Power	NA	Brown to Black	High	Coal Dust	Black Emorphous Powder	Low	Normal	Slightl y Acidic	Low
Nuclear Steam Electric Power	NA	Light Brown	Low	Oils, Lubricants	Light Brown	Low	Normal	Normal	Low

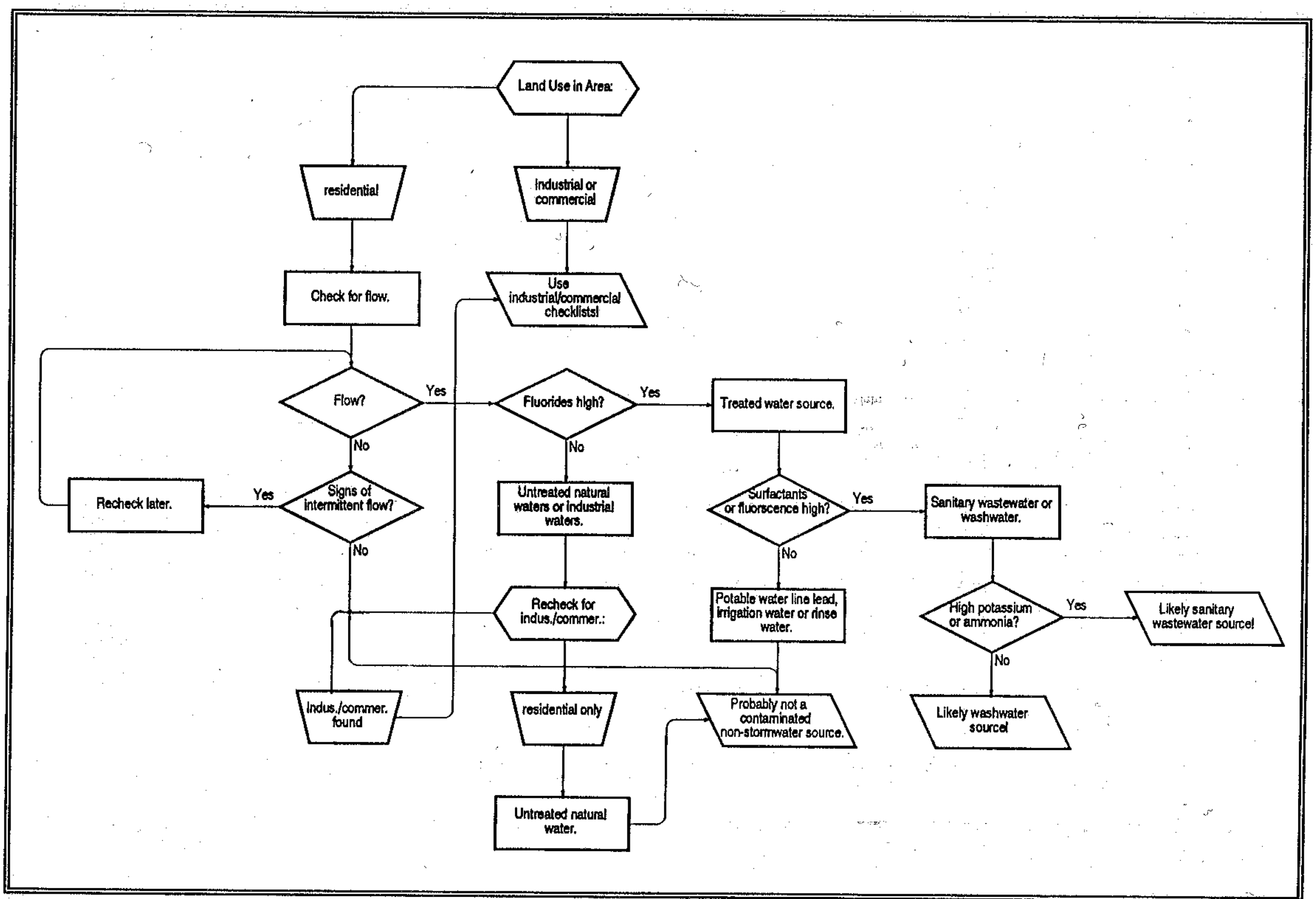

Figure 10. Flow chart to identify residential area non-stormwater flow sources.

not be an appropriate indicator.

- Hardness can also be used as an indicator if the potable water source and the baseflow are from different water sources. An example would be if the baseflow is from hard groundwater, and the potable water is from softer surface supplies.

- If the concentration of chlorine is high, then a major leak of disinfected potable water is likely to be close to the outfall. Because of the rapid dissipation of chlorine in water (especially if some organic contamination is present) it is not a good parameter for quantifying the amount of treated potable water observed at the outfall.

Water from potable water supplies (that test positive for fluorides, or other suitable tracers) can be relatively uncontaminated, e.g., potable waterline leakage or irrigation runoff, or heavily contaminated, e.g., sanitary wastewater.

<u>Sanitary Wastewaters</u>

In areas containing no industrial or commercial sources, sanitary wastewater is probably the most severe dry-weather contaminating source of storm drain flows. The following parameters can be used for quantifying the sanitary wastewater components of the treated potable water portion:

- Surfactant analyses may be useful in determining the presence of sanitary wastewaters. However, surfactants present in water originating from potable water sources could indicate sanitary wastewaters, laundry wastewaters, car washing wastewater, or any other waters containing surfactants. If surfactants (or fluorescence) are not present, then the potable water could be relatively uncontaminated (potable waterline leaks or irrigation runoff).

- The presence of fabric whiteners (as measured by fluorescence using a fluorometer in the laboratory or in the field) can also be used in distinguishing laundry and sanitary wastewaters.

- Sanitary wastewaters often exhibit predictable trends during the day in flow and quality. In order to maximize the ability to detect direct sanitary wastewater connections into the storm drainage system, it would be best to survey the outfalls during periods of highest sanitary wastewater flows (mid to late morning hours).

- The ratio of surfactants to ammonia or potassium concentrations may be an effective indicator of the presence of sanitary wastewaters or septic tank effluents. If the surfactant concentrations are high, but the ammonia and potassium concentrations are low, then the contaminated source may be laundry wastewaters. Conversely, if ammonia, potassium, and surfactant concentrations are all high, then sanitary wastewater is the likely source. Some researchers have reported low surfactants in septic tank effluents. Therefore, if surfactants are low, but potassium and ammonia are both high, septic tank effluent may be present. However, Pitt and Lalor (publication pending) found high surfactant concentrations in septic tank effluent during the Birmingham, Alabama demonstration project. This further stresses the need to obtain local site specific characterization data for potential contaminating sources.

- Obviously, odor and other physical characteristics, e.g., turbidity, coarse and floating "tell-tale" solids, foaming, color, and temperature would also be very useful in distinguishing sanitary wastewater from washwater or laundry wastewater sources. However, these indicators may not be very obvious for small levels of sanitary wastewater contamination.

FLOW-WEIGHTED MIXING CALCULATIONS

Before any flow-weighted mixing calculations can be made, the characteristics of potential contaminating sources must be identified. Table 12 summarizes hypothetical concentration medians and COVs for tracers that have been recommended to be used in the investigation of non-stormwater entries into storm drainage systems in residential areas. This method is an extension of the checklistmethod described above and attempts to quantify the likely source flow components at the outfall during dry weather.

Two general groupings of flow sources can usually be recognized for each of these tracers, a high concentration group and a low concentration group. Table 13 describes these groups, along with their composite tracer concentration ranges, variations, and medians. The outfall flow can be split between the two general groupings by simple algebra. This method can result in substantial errors if the tracer concentrations cannot be separated into distinct source groupings. The next two methods, using matrix algebra to solve simultaneous equations, do not require this simplifying assumption.

Example Calculations

The drainage area for a sampled outfall had no septic tanks or commercial and industrial land uses. The likely flow sources had source flow characteristics as described in Table 12. The required detection limits and precision for outfall characterizations must be determined, as previously described, for these source flow characteristics and desired study results. This outfall had the following tracer concentrations in a dry-weather sample:

Fluoride: 0.6 mg/L

Hardness: 200 mg/L as $CaCO_3$

Surfactants: 0.6 mg/L as MBAS

Potassium: 3 mg/L

Ammonia: 3 mg/L

The water had a slight septic odor, with some floatables of apparent sanitary wastewater origin. In addition, dry-weather flow was observed at the outfall during all visits.

It is apparent that this outfall has a direct connection(s) of raw sanitary wastewater. This method can determine the approximate mix of sanitary wastewater in the outfall flow and identify the other flow components. Table 14 summarizes the example calculations used in this analysis. The list below indicates the approximate expected source components at this outfall from this analysis:

Raw sanitary wastewater: 5%

Laundry wastewater: 5%

Groundwater: 70%

Remainder (most likely potable water, but may also contain irrigation water): 20%

This analysis did not consider the potential ranges in observed tracer concentrations and the

TABLE 12. ASSUMED SOURCE FLOW QUALITY

(All Conc. in mg/L)

Source		Fluoride	Hardness (as Ca Co_3)	Surfactants (as MBAS)	Potassium	Ammonia (N as NH_3)
Surface Waters	median COV	0.14 0.23	39 0.20	0.35 0.13	0.72 0.23	0.76 1.1
Ground-waters	median COV	0.29 0.23	250 0.14	0.05 0.13	1.7 0.40	0.22 0.63
Septic Tank Effluent	median COV	1.3 0.14	39 0.20	0.05 0.13	21 0.91	47 1.5
Raw Sanitary Wastewater	median COV	1.3 0.14	39 0.20	4.6 2.2	21 0.91	22 0.63
Laundry Wastewater	median COV	1.3 0.14	39 0.20	4.6 2.2	5.3 0.57	0.31 0.91
Irrigation Water	median COV	1.3 0.14	39 0.20	0.35 0.13	0.72 0.23	0.38 1.1

TABLE 13. CHARACTERISTICS OF SOURCE GROUPINGS

Fluorides		
surface & groundwaters		all other categories
overall range:	0.1→0.4 mg/L	1→1.5 mg/L
COV:	0.54	0.14
median:	0.20 mg/L	1.3 mg/L
Concentration ratio of medians:	6.5	
Hardness		
groundwaters		all other categories
overall range:	200→300 mg/L	30→50 mg/L
COV:	0.14	0.20
median:	250 mg/L	39 mg/L
Concentration ratio of medians:	6.4	
Surfactants		
raw sanitary wastewater & laundry wastewater		all other categories
overall range:	0.2→100 mg/L	0.04→0.4 mg/L
COV:	2.2	0.83
median:	4.6 mg/L	0.14 mg/L
Concentration ratio of medians:	33	
Potassium		
septic tank effluent & raw sanitary wastewater		all other categories
overall range:	10→100 mg/L	0.5→11 mg/L
COV:	0.91	1.2
median:	21 mg/L	2.3 mg/L
Concentration ratio of medians:	9.1	
Ammonia		
septic tank effluent & raw sanitary wastewater		all other categories
overall range:	6→380 mg/L	0.1→3 mg/L
COV:	1.5	1.3
median:	47 mg/L	0.44 mg/L
Concentration ratio of medians:	107	

TABLE 14. MIXTURE CALCULATIONS TO IDENTIFY SOURCE FLOW COMPONENTS

Fluorides: 0.6 mg/L observed at outfall

x = fraction of surface & groundwater
with concentration of 0.2 mg/L
y = fraction of treated water (all other sources)
with concentration of 1.3 mg/L
(x & y fraction concentrations taken from Table 13)

$x(0.2) + y(1.3) = 0.6$ (for a unit volume of outfall water)
$x + y = 1$ (for no other sources of fluorides)

$x = 0.63$ (surface & groundwater)
$y = 0.37$ (all other sources)

Hardness 200 mg/L as $CaCO_3$ observed at outfall

x = fraction of groundwater
with concentration of 250 mg/L as $CaCO_3$
y = fraction of all other sources
with concentration of 39 mg/L as $CaCO_3$

$x(250) + y(39) = 200$

$x = 0.76$ (groundwater)
$y = 0.24$ (all other sources)

From Fluorides and Hardness Data:

Groundwater & Surface water = 0.63
Groundwater alone = <u>0.76</u>
Surface water alone = $-0.13 \rightarrow 0$

Therefore:
Groundwater fraction = $(0.63 + 0.76)/2 = 0.7$

Surfactants: 0.6 mg/L as MBAS observed at outfall

x = fraction of sanitary & laundry wastewater
with a concentration of 4.6 mg/L as MBAS
y = fraction of all other sources
with a concentration of 0.14 mg/L as MBAS

$x(4.6) + y(0.14) = 0.6$

$x = 0.10$ (sanitary & laundry wastewater)
$y = 0.90$ (all other sources)

TABLE 14. (continued)

Potassium: 3 mg/L observed at outfall

x = fraction of sanitary wastewater with a concentration of 21 mg/L
y = fraction of all other sources with a concentration of 2.3 mg/L

$$x(21) + y(2.3) = 3$$

$$x = 0.04 \text{ (sanitary wastewater)}$$
$$y = 0.96 \text{ (all other sources)}$$

Ammonia: 3 mg/L observed at outfall

x = fraction of sanitary wastewater with a concentration of 47 mg/L
y = fraction of all other sources with a concentration of 0.44 mg/L

$$x(47) + y(0.44) = 3$$

$$x = 0.06 \text{ (sanitary wastewater)}$$
$$y = 0.94 \text{ (all other sources)}$$

From Surfactants, Potassium, and Ammonia Data:

Sanitary wastewater = (0.04 + 0.06)/2 = 0.05

Laundry wastewater = 0.1 - 0.05 = 0.05

resulting errors that may be associated with the above mixture portions. The following procedures are better suited for error analyses.

MATRIX ALGEBRA SOLUTION OF SIMULTANEOUS EQUATIONS

It is possible to estimate the outfall source flow components using a set of simultaneous equations. The number of unknowns should equal the number of equations available, resulting in a square matrix. If there are eleven likely source categories, then there should be eleven tracer parameters used. If there are only four possible sources, then only four tracer parameters should be used.

Further statistical analyses may therefore be needed to rank the usefulness of the tracers for distinguishing different flow sources. Pitt and Lalor (publication pending) show examples of how cluster and principal component analyses can be used to identify redundancy and other problems in the data library. As an example, chlorine is not useful for these analyses because the concentration variability within many source categories is high (it is also not a conservative parameter). Chlorine may still be a useful parameter, but only to identify possible large potable waterline leaks. It cannot be used to quantify the flow components. Another parameter having problems for most situations is pH. The variation of pH between sources is very low (they are all very similar). However, pH may still be useful to identify industrial wastewater problems, but it cannot be used to quantify flow components. pH is also not linearly affected by mass balance mixtures (a solution of 50 percent/50 percent of two components would not result in a pH value that is the average of the two individual pH values).

These equations are structured on a mass balance basis, like the previous procedure, but they can be used to distinguish all source categories simultaneously. A simplified example is shown in the following discussion considering just four possible flow components and four tracer parameters (P1, P2, P3, P4). This would result in the following set of equations for each outfall sample:

	possible sources:								
tracer parameter:	1		2		3		4		outfall quality
P1:	(A1)(C11)	+	(A2)(C21)	+	(A3)(C31)	+	(A4)(C41)	=	m1
P2:	(A1)(C12)	+	(A2)(C22)	+	(A3)(C32)	+	(A4)(C42)	=	m2
P3:	(A1)(C13)	+	(A2)(C23)	+	(A3)(C33)	+	(A4)(C43)	=	m3
P4:	(A1)(C14)	+	(A2)(C24)	+	(A3)(C34)	+	(A4)(C44)	=	m4

A1 through A4 represent the fraction of flow contributed from each possible flow source. The "C" terms represent concentrations from the source flow library for each particular parameter (P) within each flow source(1-4). The "m" terms represent the concentration of P actually measured in the outfall sample.

The following is an example for an outfall dry-weather sample:

possible sources:

tracer parameter:	potable water	ground water	sanitary wastewater	laundry wastewater	outfall quality
fluoride:	(A1)(0.97 mg/L)	+ (A2)(0.031 mg/L)	+ (A3)(0.77 mg/L)	+ (A4)(33 mg/L)	= 3.8 mg/L
hardness:	(A1)(49 mg/L)	+ (A2)(240 mg/L)	+ (A3)(140 mg/L)	+ (A4)(14 mg/L)	= 126 mg/L
surfactants:	(A1)(0 mg/L)	+ (A2)(0 mg/L)	+ (A3)(1.5 mg/L)	+ (A4)(27 mg/L)	= 3.0 mg/L
potassium:	(A1)(1.6 mg/L)	+ (A2)(0.73 mg/L)	+ (A3)(6.0 mg/L)	+ (A4)(3.5 mg/L)	= 2.2 mg/L

This simple 4x4 matrix can be solved using available scientific calculators or math programs for personal computers, or by hand. For this example, the following are the approximate flow components (rounded to the nearest 5 percent):

- treated potable water (A1): 30%
- groundwater (A2): 35%
- sanitary wastewater (A3): 20%
- laundry wastewater (A4): 10%

These component contributions do not all add up to 100 percent. A number of errors, especially variations in source area characteristics and other sources present that were not considered, tend to result in component sums that are not 100 percent. The following method is similar, but considers uncertainty in source/area characteristics and results in a range of likely component contributions.

MATRIX ALGEBRA CONSIDERING PROBABILITY DISTRIBUTIONS OF LIBRARY DATA

A stochastic version of the above procedure enables the variation in the library values to be considered. The matrix is set up in the same way, but instead of using a single value representing the parameter concentration for each likely source flow, a Monte Carlo simulation is used to randomly select values. A large number of analyses (from a few hundred to many thousands) are conducted and the percentage contributions for each component source are presented as a probability distribution instead of a single value.

It is therefore necessary to describe the distribution of source flow characteristics. In most cases, the tracer parameters can be represented using log-normal distributions. Some parameters, however, are adequately described with normal distributions. Again, local source flow monitoring is necessary to obtain this information. Pitt and Lalor (publication pending) contains examples using this method, including the code for the necessary computer program.

SECTION 7

WATERSHED SURVEYS TO CONFIRM AND LOCATE INAPPROPRIATE POLLUTANT ENTRIES TO THE STORM DRAINAGE SYSTEM

After initial outfall surveys have indicated the presence of contamination, further detailed analyses are needed to identify and locate the specific contaminant source(s) (e.g., residential, commercial, and/or industrial) in the drainage area. For source identification and location, upstream survey techniques should be used in conjunction with an in-depth watershed evaluation. Information on watershed activities can be obtained from aerial photography and/or zoning maps, while upstream survey techniques will include the analysis of the dry-weather flow at several manhole points along the storm drainage system to narrow the location of the contaminating source; tests for specific pollutants or ions associated with known activities within the outfall catchment area; and the measurement of water flow rate and temperature, visual and T.V. inspections, and smoke and dye tests.

USING TRACER PARAMETERS IN THE DRAINAGE SYSTEM

In order to identify the specific contaminant sources in the drainage system, further detailed watershed analyses are needed. These may include:

- drainage system surveys (tests for specific pollutants, visual inspections, T.V. drainage pipe inspections, and smoke and dye tests),
- in-depth watershed evaluation (including aerial photographs), and
- industrial and commercial site studies.

Review Industrial User Surveys or Reports

This will require the submission of a questionnaire to industries to determine which industries or commercial locations are discharging to a storm drainage system. However site inspections will still be required because questionnaires may not be returned or may give incorrect details (either deliberately or unknowingly).

Follow-up Drainage Area and On-Site Investigations.

Further drainage area investigations upstream of identified problem outfalls would be conducted after the outfall studies have indicated dry-weather discharge problems. In order to be cost-effective, only a sub-sample of manholes located in a drainage area identified as having significant non-stormwater sources should be tested for the tracers. As an example, the main storm drain trunk sewer could be divided into tenths and the manholes closest to these subdivisions would be sampled. This would identify the upper limit of the drainage area above which the major sources are not located. A location may also be identified where the downstream manhole tracer mass yields (concentration times flow rate) are the same. This would mark the downstream limit of the contributing area for the tracers of concern. After the main trunk drainage reach is identified that contains the major non-stormwater sources, the branch storm drain lines can be similarly subdivided (but into fewer sections each, perhaps about three) and evaluated. Depending on the drainage area and complexity of the storm drainage system, this scheme could be suitably modified to enable the identification of relatively small areas responsible for the non-stormwater pollutant entries into the storm drainage system. These small areas would then be subject to the more intensive on-site investigations by smoke tests, dye studies, and T.V. inspections.

The above drainage system analysis procedure may find that the drainage system is contaminated by widespread sanitary wastewater entries, possibly due to sanitary and storm drainage systems in extremely poor condition. This situation may require that the drainage system undergo extensive and costly repairs. It may be more appropriate to consider the storm drainage system as a combined sewer and examine control alternatives that have been developed for combined sewer systems. This would also save further detailed drainage system analyses costs.

These drainage system surveys would be followed by industrial and commercial on-site investigations (e.g., dye and smoke studies and T.V. inspections) to locate specific sources of non-stormwater pollutant entries into the drainage system. Additionally, aerial photography can be very useful during later phases of non-stormwater discharge control projects. As an example, aerial photography can help identify areas having failing septic systems located in residential areas served by storm drainage systems. Aerial photography can also be used to identify continuous discharges to surface drainage systems, such as sump discharges, and to identify storage areas that may be contributing significant amounts of pollutants during rains. For example, the Tennessee Valley Authority (TVA), among other agencies, has extensively used aerial photography (stereo color infrared) to identify pollution sources, especially from failing septic tanks (Perchalski and Higgins 1988). The TVA's flights are made in early spring when investigating septic tank failures, to be able to identify unusual grass conditions, with minimal interference from trees. The flights are made at 6,000 feet, with resulting image scales of 1 inch to 1,000 feet. Their photography costs have been about $40 to $150 per square mile.

FLOW MASS BALANCES, DYE STUDIES, AND SMOKE TESTS

Industrial areas are known to contribute significantly polluted wet-weather stormwater discharges, along with contaminated dry-weather entries into the storm drainage system. Additional industrial site investigations are therefore needed to identify activities that apparently contribute these contaminants to the storm drainage system. Figure 11 is an industrial site survey form prepared by the Non-Point Source and Land Management Section of the Wisconsin Department of Natural Resources (R. Bannerman, personal communication). This form has been used to help identify industrial activities that contribute significantly polluted, indirectly connected dry- and wet-weather non-stormwater entries into the storm drainage system.

This form only considers outside sources that would affect the storm drainage system by entering through inlets or through sheetflow runoff into drainage channels. It does not include any information concerning indoor activities, or direct plumbing connections to the storm drainage system. However, the information included on this form can be very helpful in devising runoff control programs for industrial areas. This information most likely affects wet-weather discharges much more than dry-weather discharges. Obvious dry-weather leaching or spillage problems are also noted on the form.

Locating An Industrial Source

Hypothetical examples have been created to demonstrate how dry-weather discharges can be characterized so that their likely industrial sources can be identified. These examples show how observations of outfall conditions and simple chemical analyses, combined with a basic knowledge of wastewater characteristics of industrial and commercial operations located in the drainage area, can

City: ______________________ Industry Name: ______________________
Site Number: ______________________ Photo # ______________________
Street Address: ______________________ Roll # ____________
Type of industry: ______________________
Instructions: Fill in blanks or circle best answer in following:

Material/waste Storage Areas
1. Type of material/waste: ______________________
2. Method of storage: pile tank dumpster other ______________________
3. Area occupied by material/waste (acres): ______________________
4. Type of surface under material/waste: paved unpaved
5. Material/waste is disturbed: often sometimes never unsure
6. Description of spills (material, quantity & frequency): ______________________
7. Nearest drainage (feet) and drainage type: ______________________
8. Control practice: berm tarp buffer none other ______________________
9. Tributary drainage area, including roofs (acres) ______________________
10. Does storage area drain to parking lot: yes no unsure

Heavy equipment storage
1. Type of equipment: ______________________
2. Area covered by equipment (acres): ______________________
3. Type of surface under equipment: paved unpaved
4. Nearest drainage (feet) and drainage type: ______________________
5. Control practice: berm tarp buffer none other ______________________
6. Tributary drainage area, including roofs (acres) ______________________
7. Does storage area drain to parking lot: yes no unsure

Air pollution
1. Description of setteable air pollutants (types & quantities): ______________________
2. Description of particulate air pollutant controls: ______________________

Railroad yard
1. Size of yard (number of tracks): ______________________
2. General condition of yard: ______________________
3. Description of spills in yard (material, quantity & frequency): ______________________
4. Type of surface in yard: paved unpaved
5. Nearest drainage (feet) and drainage type: ______________________
6. Type of control practice: berm buffer other ______________________
7. Does yard drain to parking lot: yes no unsure
8. Tributary drainage area, including roofs (acres): ______________________

Loading Docks
1. Number of truck bays: ______________________
2. Type of surface: paved unpaved
3. Description of spills in yard (material, quantity & frequency): ______________________
4. Nearest drainage (feet) and drainage type: ______________________
5. Type of control practice: berm buffer other ______________________
6. Does loading area drain to parking lot: yes no unsure
7. Tributary drainage area, including roofs (acres): ______________________

Source: From Wisconsin Dept. of Natural Resources (R. Bannerman Personal communication)

Figure 11. Industrial Inventory Field Sheet. (Use other sheets for multiple areas on same site)

be used to identify the possible pollutant sources. The initial activities include pollutant analyses of outfalls being investigated. This requires the characterization of the non-stormwater flows, the identification of the likely industries responsible for the observed discharges, and finally, locating the possible specific sources in the watershed.

Hypothetical Conditions--

The hypothetical industries which were identified as being located in a stormwater drainage area (from the watershed analysis) included a vegetable cannery, general food store, fast food restaurant, cheese factory, used car dealer, cardboard box producer, and a wood treatment company. The methods used to determine the most likely industrial source of the dry-weather discharges are considered for three hypothetical situations of outfall contamination.

Case Example One--The hypothetical results of the pollutant analysis for the first situation found constant dry-weather flow at the outfall. The measurements indicated a normal pH (6) and low total dissolved solids concentrations (300 mg/L). Other outfall characteristics included a strong odor of bleach, no distinguishing color, moderate turbidity, sawdust floatables, a small amount of structural corrosion, and normal vegetation.

The significant characteristic in this situation is the sawdust floatables (see Figure 12). The industries which could produce sawdust and have dry-weather flow drainage to this pipe are the cardboard box company and the wood treatment company. According to SIC code, the cardboard box company would fall under the category of "Paper Products" (SIC# 26) while the wood treatment company would be under that of "Lumber and Wood" products (SIC# 24). Looking up these two industries by their corresponding SIC group numbers in Table 11 and comparing the listed properties, indicates that the paper industry has a strong potential for the odor of bleach. Wood products does not indicate any particular smell.

Based upon this data, the most likely industrial source of the industrial non-stormwater discharge would be the cardboard box company. Table 2 under SIC# 26 indicates that there is a high potential for direct connections in paper industries under the categories of water usage and illicit or inadvertent connections. At this point, further testing should be conducted at the cardboard box company to find if the constant source of contamination is coming from cooling waters, process waters, or direct piping connections (process waters are the most likely source given the bleach and sawdust characteristics).

Case Example 2--The results of the pollutant analysis for the second situation found intermittent dry-weather discharges at the outfall. The test measurements indicated a low pH (3) and high total dissolved solids concentrations (approximately 6,000 mg/L). Other characteristics included a rancid-sour odor, grayish color, high turbidity, gray deposits containing white gelatin-like floatable material, structural damage in the form of spalling concrete, and an unusually large amount of plant life.

The rancid-sour smell and the presence of floatable substances at this outfall indicates that some type of food product is probably spoiling. This narrows the possible suspect industries to the fast food restaurant, cheese factory, vegetable cannery, and food store (see Figure 13). The corresponding SIC categories for each of these industries are "Eating and Drinking Places" (SIC# 58), "Dairy Products" (SIC# 202), "Canned and Preserved Fruits and Vegetables" (SIC# 203), and "Food Stores" (SIC# 54). Comparison of the properties listed in Table 11 for these SIC numbers indicates that elevated plant life is common to industrial wastes for the "Dairy Products" and "Food Stores" categories. However, the deciding factor is the low pH, which is only listed for "Dairy Products". Thus, the white gelatin-like floatables are most likely spoiled cheese byproducts which are also the probable cause of the sour-rancid smell.

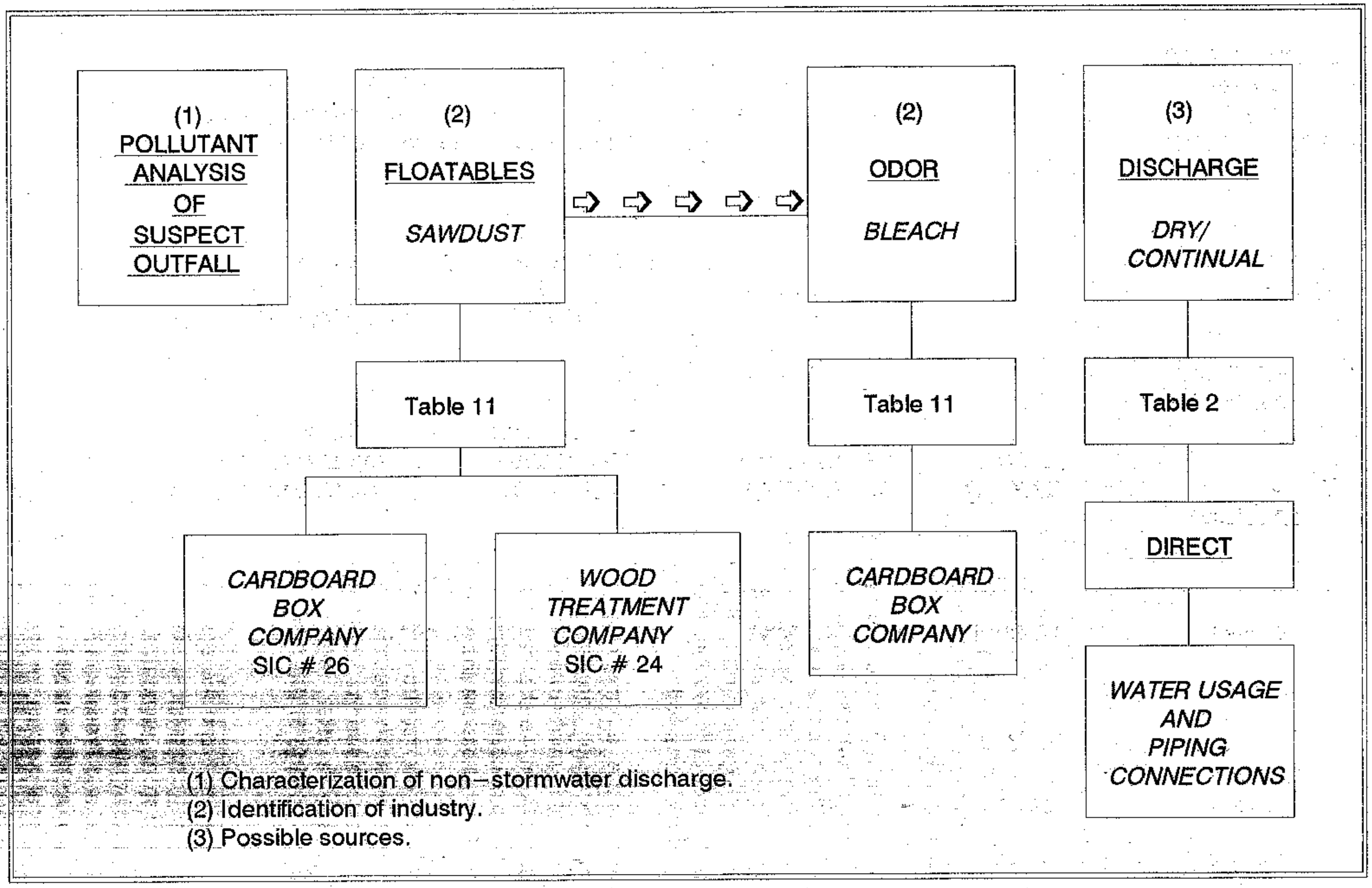

Figure 12. Flowsheet for Industrial Case 1.

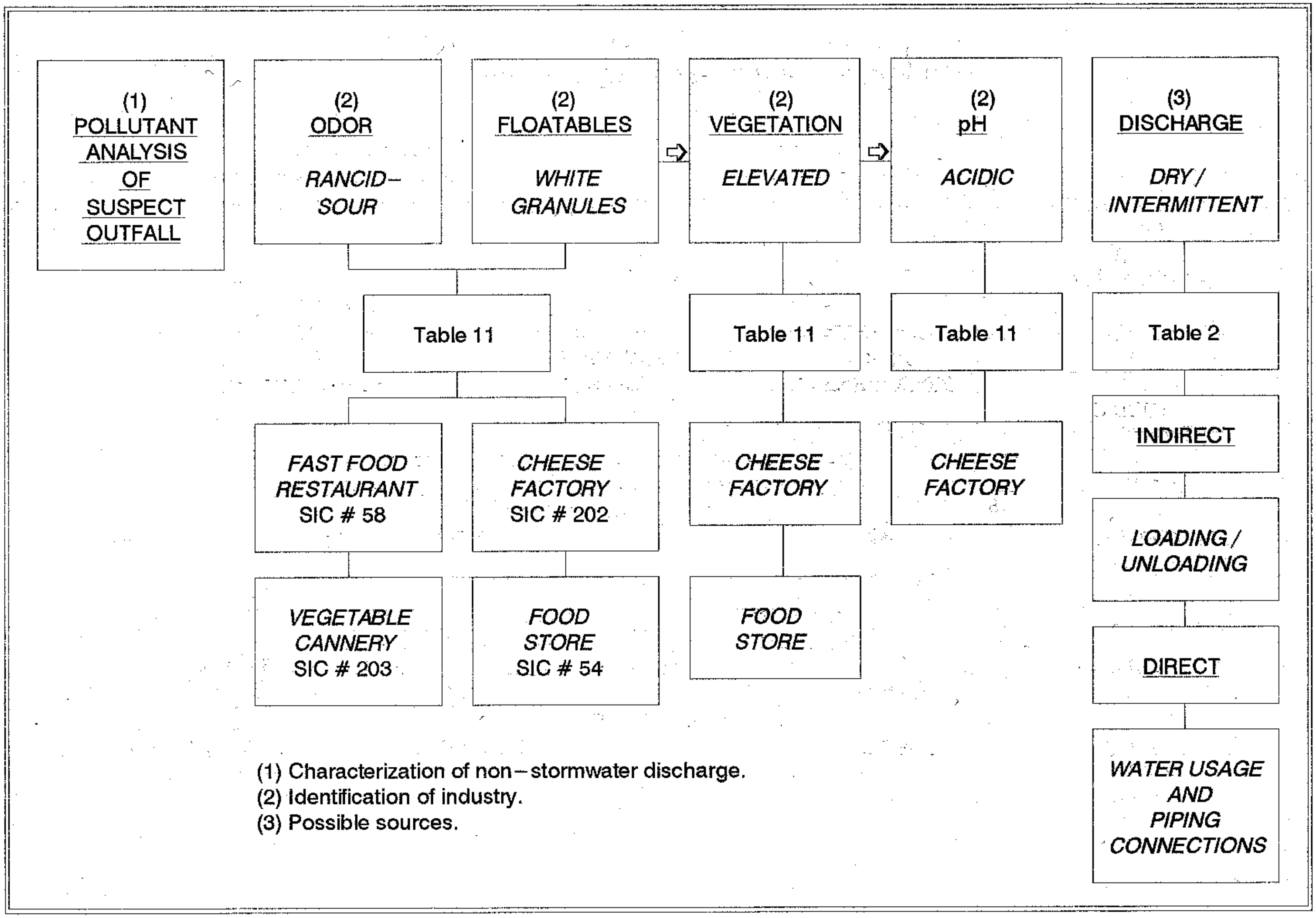

Figure 13. Flowsheet for Industrial Case Example 2.

Since the dry-weather entry to the storm drainage system occurs intermittently, the flow could be caused by either a direct or indirect connection. To locate the ultimate source of this discharge coming from the cheese factory, both direct and indirect industrial situations are considered under the category of "Dairy Products" in Table 2. Thus, further examination of the loading dock procedures, water usage, and direct piping connections should be conducted since these categories all exhibit high potential for pollution in dairy production.

Case Example 3-- The results of the test measurements for the final situation found a normal pH (6) and low total dissolved solids (about 500 mg/L). Signs of contaminated discharges were found at the outfall only during and immediately following rainfalls. Other outfall properties observed included an odor of oil, deep brown to black color, a floating oil film, no structural damage, and inhibited plant growth (see Figure 14).

According to Table 11, the fast food restaurant and the used car dealer are the only two industrial sources in this area with high potential for causing oily discharges. Their respective SIC categories are "Eating and Drinking Places" (SIC# 58) and "Automotive Dealers" (SIC# 55). Comparison of the properties shown on Table 11 indicates inhibited vegetation only for the second category. Thus, the most likely source of the discharge is the used car dealer.

Furthermore, the source of contamination must likely be indirect, since the discharge occurs only during wet weather. Reference to Table 2, under the category of "Automotive Dealers", indicates a high potential for contamination due to outdoor storage. This fact, plus the knowledge that most used cars are displayed outdoors, makes it fairly clear that surface runoff is probably carrying spilled car oil into the storm drain during rains.

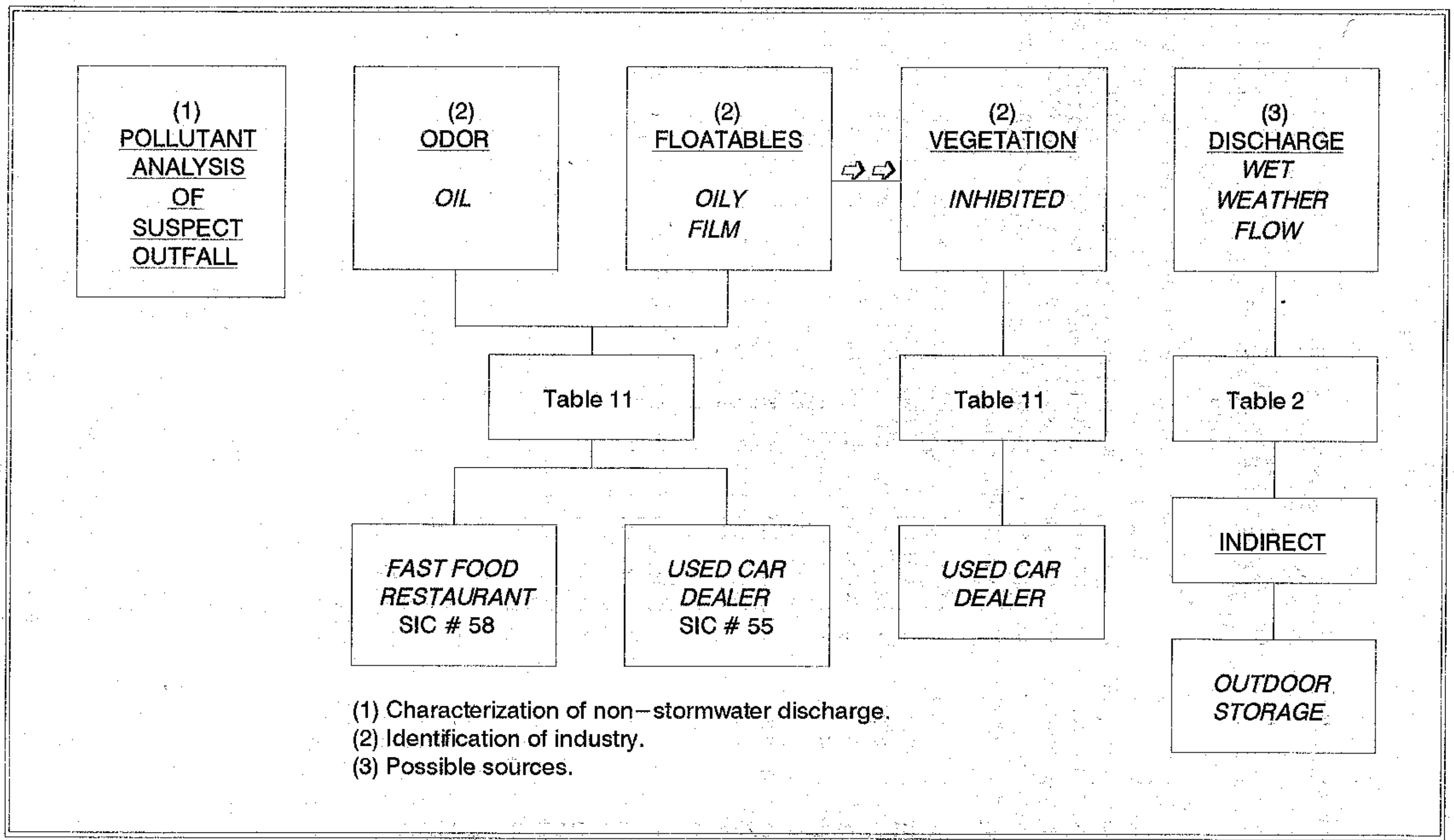

Figure 14. Flowsheet for Industrial Case Example 3.

SECTION 8

CORRECTIVE TECHNIQUES

In addition to identifying problems of unauthorized or inappropriate entries to stormwater systems, it is even more important to prevent problems from developing at all, and to provide an environment in which future problems will be avoided. Thus, a combined approach of identifying and correcting existing problems and avoiding future problems has considerable merit. In this section, the focus is on discussing ways in which future problems can be avoided. However it should be noted that this is not an in depth review, but has been included to provide the reader with suggestions that could be incorporated into a pollution prevention program.

There are also situations in which the sanitary system is so connected to the stormwater system that good intentions, vigilance, and reasonable remedial actions will not be sufficient to solve the problems. In an extreme case, it may be that while it was thought that a community had a separate sanitary sewer system and a separate storm drainage system, in reality the storm drainage system is acting as a combined sewer system. When recognized for what it really is, the alternatives for the future become clearer: undertake the considerable investment and commitment to rebuild the system as a truly separate system, or recognize the system as a combined sewer system, and operate it as such, without the disillusionment that it is a problem-plagued storm drainage system which can be rehabilitated.

Less extreme than designating a polluted stormwater drainage system a combined sewer system, is the action of focusing on pollution prevention by:

- public education,
- an organized systematic program of disconnecting commercial and industrial non-stormwater entries into the storm drainage system,
- tackling the problem of widespread septic system failure,
- disconnecting direct sanitary sewerage connections,
- rehabilitating storm or sanitary sewers to abate contaminated water infiltration, and
- developing zoning and ordinances.

In this section, the above items will be discussed, together with a section on treatment of wide spread sanitary sewerage failure.

PUBLIC EDUCATION

One can argue that an ill informed and apathetic public has condoned the past actions of private citizens, commercial entities, industrial concerns, and public officials which led to some of the past and present problems with unauthorized entries to storm drainage systems. One also knows the power of an aroused, concerned public in altering behavior at all levels. Thus, public education has a role to play. It can be effective in altering the behavior of an individual who had assumed that the inlet on the curb was the place to discharge used crankcase oil. It can be effective when organized groups lobby for the return of a stream or a reservoir to a clean and attractive condition.

Public education carries with it the implicit assumption that an educated public will make the "right" decisions, the educated public will be concerned about the "right" problems, and it will encourage private and public organizations to develop solutions to the "right" problems. Fortunately, most of the problems, issues, and corrective measures are clear cut with respect to unauthorized entries to the stormwater system. Public education is a communication art associated with significant changes when successful, and imperceptible change when unsuccessful. As with all education, it does not end, but is a continuing process. The following paragraphs describe some of the ways in which public officials can help to educate the public. The "public" has been subdivided into categories which are representative of the problem areas with respect to unauthorized entries to storm drainage systems. The subcategories of the public are:

- industrial
- commercial
- residential
- governmental

Industrial decision makers can be educated by public officials through direct contact when they seek information, by education of the consultants from whom industry seeks advice, and by education of trade associations. Indirect educational opportunities are provided by speaking to meetings of professional organizations and by writing in professional newsletters and journals. Industrial decision makers are a small group which is likely to respond as they recognize that they have to address the problem of unauthorized entries to the stormwater system.

Commercial storm drainage system users are a larger group to educate. The educational process will have to focus on both proprietors and their employees. It will have to recognize the state of both groups, new businesses opening; existing businesses moving, expanding, and closing; and employees entering the work force and changing jobs. Education will have to be focused in the local community. The role of trade and professional associations will be less than was the case with industrial groups. News announcements in the local press will play a role as well as mailed news items. Individual contact between a public official and the proprietor of a commercial establishment will play a larger role. Follow up and repeated contact may be necessary to answer questions and cope with employee turnover. Public education can also benefit from failures. For example, certain violations of discharge practices may be so serious, or flagrant, that a citation or fine results. The local press, if informed, may find such an incident newsworthy. The general public, or other potential offenders, may benefit from this educational procedure.

An informed public willing to act on their convictions is the product sought from public education. The public educator focuses on large groups, as one-on-one contact is unlikely to be either time or cost effective. Long range educational goals may be tackled through school programs, while shorter range educational goals may focus on community groups. Public education will have to focus on broader environmental issues than inappropriate entries to storm drains. Subgroups in the community may play important roles in public education. For example, scouts may undertake community improvement projects including placing signs on curbside storm drains informing the public that the drain is for stormwater only, and not for discharge of wastes. Thus, public education must take advantage of opportunities presented by groups looking for community improvement projects, the opportunities that are available in working with the school system, and opportunities arising from the news media being supplied with newsworthy items.

The final group that public officials should address in public education is other public officials and governmental institutions. Some small governmental units may not know about precautions to be taken with discharges to storm drainage systems unless they are properly informed. Such subgroups may include road departments, sanitation workers, and workers at public institutions such as hospitals and prisons. A multilevel, multitarget public education program can help to avoid problems.

COMMERCIAL AND INDUSTRIAL SITE DISCONNECTIONS OF NON-STORMWATER SOURCES

Out of convenience and out of ignorance, commercial and industrial sites may impose an increasing load on the storm drainage system. This may be through direct discharges to the storm drainage system, or it may be through diffuse and indirect sources in which the site grounds are contaminated by spills and discharges which are then washed off by storm runoff to the storm drain during rainfall events or by washwater during wash-down operations. The problem is compounded by the vast array of sizes of commercial and industrial enterprises. A single person enterprise has little opportunity to build expertise on the subject of stormwater pollution, while a large industrial enterprise may have an environmental division. To the uninformed person, any curb opening may be thought to be part of a comprehensive sanitary wastewater treatment system and the proper entrance point for polluted water discharges or other debris.

Corrective measures for improper uses of storm drains have to be developed recognizing the differences in knowledge and sophistication of the client. Industrial users are relatively few in number but are expected to have the most complex problems. If industrial users are aware, or made aware, of existing and or new federal, state, or local regulations to prevent pollution of stormwater drainage systems, they will usually comply with the regulation. If not, these regulations provide the authority and communication means to instigate corrective action.

Commercial groups are heterogeneous. An appropriate way of working with them to institute changes in their use of storm drainage systems, may be to work with one category of commercial groups at a time. For example, consider gasoline filling stations as a single category. It is possible to focus on correcting similar problems at many facilities that exist in this category. The flushing of radiators may be seasonally common. A typical practice is to let radiator flushing waters (including coolants) to drain to an inlet to the storm drainage system. Education followed by assurance that there will be strict enforcement of discharge regulations or ordinances may be effective. However, a group such as gasoline filling stations cannot be expected to have a long institutional memory as new operators take over and others drop out. Thus, vigilance and follow-up are important to insure that there is not a gradual diminution of appropriate practices.

For both small commercial and large industrial enterprises, willful and knowledgeable violation of the regulations limiting entries to storm drainage systems have to be dealt with firmly and promptly or the enforcement program runs the chance of becoming ineffective. Thus the governmental unit undertaking responsibility for improving the practices regarding entries to storm drainage systems must have an enforcement plan ready.

FAILING SEPTIC TANK SYSTEMS

Failing septic tank systems can have an impact on an otherwise well functioning storm drainage system. Before discussing corrective measures, it is important to identify the relationship that may develop between a septic tank system and a storm drainage system.

A septic tank system consists of two major components: a septic tank and a leaching field (a waste spreading or soil absorption system). In addition, of course, there is piping associated with the system. Sanitary wastewaters are piped directly to the septic tank. The septic tank typically is made of concrete, is rectangular in shape, is usually divided into two compartments, and has a capacity of one to several thousand gallons. The septic tank serves as an anaerobic digestion, floatation and settling unit in which biological action converts the biodegradable liquid and solid waste particles into stable end products. Gravity separates a significant portion of both biodegradable and non-biodegradable particulate matter to the tank bottom or top (depending on whether the particles sink or rise, respectively). Some of the products of this partial treatment process are carbon dioxide, methane, hydrogen sulfide and other odor producing gases, digested and refractory or relatively non-biodegradable sludge, and floating scum. Because the septic tank remains full, it must discharge a volume of wastewater each time a volume of wastewater is discharged into it. This discharged water enters a leaching field where some additional treatment occurs and the final effluent is discharged to the ground.

A septic tank may be a low maintenance treatment unit, but it is not entirely maintenance free. As the septic tank continues to be loaded, the scum and sludge layers build up so that the remaining volume available for treatment is reduced. Thus, some of the partially digested or undigested solids, scum, and sludge may be carried from the septic tank to the leaching field where the soil void space may become clogged. As the soil voids become clogged, the ability of the leaching field to handle the liquid portion of the waste is reduced, and surface ponding of the wastewater may result. Of course, ponding could have been prevented by having the septic tank serviced; that is, by having the septic tank pumped. Pumping removes the sludge, scum, and other contents of the septic tank so that its storage and treatment capacity is restored. Pumping frequency varies depending on the size of the septic tank and its loading rate. Residential septic tanks may need to be pumped every two to five years. Commercial and institutional septic tanks may need more frequent pumping.

Failed septic tank systems have the potential to pollute stormwater because the leaching field will saturate the ground, and possibly form ponded water on the ground surface. The ponded water may run off and enter a storm drain inlet or drainage ditch, or infiltrate the ground in another area which is intercepted by a storm drain through infiltration. When it rains, any remaining ponded water may be washed off with the runoff to the storm drainage system. Depending on the severity of the septic tank failure, the ponded water can have the characteristics of partially treated sanitary wastewater or nearly untreated sanitary wastewater. Thus, septic tank failures can contaminate the stormwater drainage system during both wet and dry weather.

Septic tank systems may fail even with good maintenance practices. Such failure can result when the soil is simply not permeable enough for the leaching field, or when the soil absorbance capacity is exceeded through long use. A tight clay soil may have such low permeability that the leaching capacity is very limited. If a number of homes are built in close proximity, their septic tank leaching fields may collectively exceed the soil's capacity, leading to a stormwater pollution problem. Even properly operating septic tank systems are a potential pollutant source. Because the basic function of the leaching field is to discharge partially treated effluent to the ground, this septic tank effluent can infiltrate into nearby stormwater drainage systems.

Various corrective methods exist for failing septic tank systems that pollute stormwater. These methods include: improve maintenance, institute preventative measures to avoid problems, and abandon the septic tank system with connections made to a sanitary sewerage system. In some cases, improved maintenance may be the answer. Some persons will not do any maintenance to their septic tank system until it fails (they note ponded water in the leaching field area). Then they call for the septic tank to be pumped. In many cases, this is not sufficient to correct the problem: it may be too little action too late. The preventative action of having the septic tank pumped should have taken place prior to failure of the system. Education may provide part of the remedy. The septic tank user may respond to exhortations to have the septic tank pumped on a regular basis, before failure. Coercion through ordinances may be another answer. Ordinances may require that the septic tank be pumped at a specified frequency, with a public body monitoring the program to ensure that maintenance has been carried out.

It sometimes happens that soil conditions and population density rule out both voluntary or involuntary maintenance. In this case, it may be necessary to consider abandoning the septic tank system and installing a system consisting of sanitary sewers leading to a treatment plant. Another option consists of abandoning the septic tank treatment method in favor of small package treatment units that provide aerobic treatment of the sanitary wastewater which is then discharged to a regional leaching field. This option may succeed where the septic tank system has failed, because wastes treated in an aerobic unit may not have the leaching field clogging potential of wastes treated in an anaerobic septic tank. However, experience has shown that these advantages are only obtained with proper control and maintenance. Aerobic systems are more sensitive than conventional septic tank systems to improper maintenance and may therefore not offer any real benefits.

DIRECT SANITARY SEWERAGE CONNECTIONS

Due to indifference, ignorance, poor enforcement of ordinances, or other reasons, a stormwater drainage system may have sanitary wastewater sewerage direct connections. Obviously, the sanitary wastewater entering the storm drain will not receive any treatment and will pollute a large flow of stormwater, in addition to the receiving water. If the storm drain has a low dry-weather flow rate, the presence of sanitary wastewater may be obvious due to toilet paper, feces, and odors. In cases of high dry-weather flows, it may be more difficult to obviously detect raw sanitary wastewaters due to the low percentage of sanitary wastewater in the mixture. Even though the sanitary wastewater fraction may be low, the previously discussed field testing procedures (e.g., testing for surfactants, ammonia, potassium, and fluorides) will assist in the detection and quantification of sanitary wastewater contamination in the storm drainage system. Flow monitoring may show the variations in the flow rate that are typical of sanitary wastewater.

Dye testing can be effective in finding specific sanitary wastewater connections between a house and a storm drainage system. Dye, such as diluted rhodamine or fluorescein, is flushed down the toilet of a house and the storm drain is monitored to determine whether the dye appears. Care has to be exercised when using this method, as these dyes may stain fixtures that are being tested, and any spillage in the house causes stains that are very difficult to remove.

Monitoring of the storm drainage system with television cameras can show the locations of breaks in the storm drain where a sanitary wastewater sewer or house lateral was attached. Television cameras may also show discharges taking place at these locations, demonstrating that the lines are in active use.

Corrective measures involve undertaking a program of disconnecting the sanitary sewer connections to the storm drainage system and reconnecting them to a proper sanitary wastewater sewerage system. The storm drainage system then has to be repaired so that the holes left by the disconnected sanitary sewer entrances do not become a location for dirt and groundwater to enter.

REHABILITATING STORM OR SANITARY SEWERS TO ABATE CONTAMINATED WATER INFILTRATION

Infiltration of contaminated water into a stormwater drainage system can cause substantial pollution of the system. This could occur where a sanitary sewer overlies and crosses (or parallels) a storm drain, with sanitary wastewater exfiltrating from the sanitary sewer and percolating the storm drain. Other instances would be in areas of polluted groundwater, where the storm drainage is below the water table or intercepts infiltrating groundwater, or in areas having septic tank systems, as discussed previously.

It would be best to correct the sanitary sewer if only one drainage system can be corrected. This would have the dual advantage of preventing infiltration of high or percolating groundwaters and preventing pollution of stormwater with exfiltrating sanitary wastewater. Rehabilitation of the drainage systems by use of inserted liners, or otherwise patching leaking areas, are possible corrective measures. It is important that all drains with infiltration problems be corrected for this corrective action to be effective. This would also include repairing house lateral sanitary wastewater lines, as well as the main drainage runs. However, these corrective measures are more likely to be cost effective when only a relatively small part of the complete drainage systems require rehabilitation.

ZONING AND ORDINANCES

Land use controls achieved by zoning have the potential to exacerbate problems or diminish them. For example, in an area with soils that are ill suited for septic tanks and leaching fields, the potential for future problems is increased if zoning allows small lots for single family residential development and allows septic tank systems. As the area develops, septic tank failures will become common, resulting in increased pollution of stormwater and groundwater. On the other hand, in areas having poor soils, zoning can require correspondingly larger lot sizes and larger leaching fields, resulting in fewer future problems. Ordinances may specify the results that have to be achieved by infiltration tests used to size leaching fields. Also, ordinances can require that a responsible public official be present when the infiltration test is run to decrease the likelihood of false or spurious results being reported. Certified septic tank installers, also checked by public official inspectors, should also be required to increase the likelihood of the system being installed correctly.

Zoning can also have a role to play in avoiding development of land that is subject to frequent flooding. In such land, flooding and high groundwater conditions can result in the sanitary sewerage system being gradually overloaded by infiltration so that cross flow to the storm drainage system can occur.

Ordinances can help to control problems by putting the force of law and public policy behind desirable practices. For example, ordinances can make mandatory practices such as septic tank maintenance that otherwise would be voluntary. By making the practice mandatory, desirable practices are performed on a regular schedule so that large problems have less opportunity to develop. Ordinances can also regulate the persons doing the pumping of septic tanks so that they discharge the septage to wastewater treatment plants where it can be properly treated rather than it being discharged improperly where the pollution problem is just transferred from one location to another.

Ordinances can also help prevent and or control pollution from many other sources by restrictions on: disposal of household toxic substances to storm drains, storage of chemicals by industry, disposal of industrial wash down water, etc.

Zoning and ordinances represent important means for governing bodies to anticipate problems, to avoid problems, and to manage problems, so that desirable ends are achieved and undesirable consequences are avoided. Enactment of zoning and ordinances occurs in the public arena where interested persons can participate and express their views and concerns. The public can become educated in this process, but zoning and ordinances have the desirable characteristic of being remembered and remaining enforceable long after an individual forgets, becomes disinterested, or becomes recalcitrant.

Another important step that municipalities can take is the development of policies and procedures for the management of spills from transportation (including both roadway and rail) and pipeline accidents. Spills should not be merely washed into the storm drainage system, but should be collected for proper treatment and disposal.

WIDESPREAD SANITARY SEWERAGE FAILURE

Connections (whether directly by piping or indirectly by exfiltration or infiltration) of sanitary sewers to the storm drainage system may be so widespread that the storm drainage system has to be recognized as a combined sewer system. This could also be the case when the prevalence of septic tank failures leads to widespread sanitary wastewater runoff to the storm drainage system. One usually thinks of a combined sewer system as having all of the sanitary sewer connections to the same sewers that carry stormwater, but the previous discussion suggests that there are degrees of a storm drainage system becoming a combined sewer system. Previously, the recommendations have been made that widespread failure of septic tank systems might necessitate the construction of a sanitary sewer to replace the septic tanks. Also recommended was a program of identifying and disconnecting sanitary sewers from the storm drainage system.

Prior to these actions taking place, the storm drainage system operates to some degree as a combined sewer system. It may be that the sanitary sewerage system is not capable of handling the load that would be imposed on it if a complete sewer separation program were undertaken. Or, in an extreme case, no sanitary sewer system may exist. By recognizing that a combined sewer system does in fact exist may help to focus attention on appropriate remedial measures. The resources may also not be available to undertake construction of a separate sanitary wastewater drainage system.

One should then focus on how to manage the combined sewer system that is in place. Management may require that end-of-pipe storage/treatment be investigated. Also, the combined sewer system may be tied into other combined sewers so that more centralized treatment and storage can be applied. Operation of a combined sewer system may be preferable to having the stormwater and the large number of sanitary entries receive no treatment.

An early identification and decision to designate a storm drainage system a combined sewer system, will prevent abortive time and costs being spent on further investigations. These resources can then be more effectively used to treat the newly designated combined sewer system.

In essence, recognition of a system as being a combined sewer system provides a focus in the regulatory community so that it may be possible to operate the system so as to minimize the damage to the environment.

GLOSSARY

Accuracy - The combination of bias and precision of an analytical procedure which reflects the closeness of a measured value to a true value.

Baseflow - The dry-weather flow occurring in a drainage system, with no apparent source. Likely to be mostly infiltrating groundwaters in a sanitary or storm drainage system, but can also be contaminated with illicit wastewaters. See constant (or continual) dry-weather flow.

Batch dump - The disposal of a large volume of waste material during a short period of time. Usually an industrial waste.

Bias - A consistent deviation of measured values from the true value, caused by systematic errors in a procedure.

Coefficient of Variation (COV) - A measure of the spread of data (ratio of the standard deviation to the mean).

Combined Sewer - A sewer designed for receiving surface (dry- and wet-weather) runoff, municipal (sanitary and industrial) wastewater, and subsurface waters from infiltration. During dry weather, it acts as a sanitary sewer, but it also carries stormwater from wet-weather runoff.

Combined sewer overflow (CSO) - Flow from an outfall (discharge conduit) of a combined sewer collection system, in excess of the interceptor capacity or due to a malfunctioning or improperly set flow regulator, that is discharged into a receiving water and/or an auxiliary CSO control storage-treatment system.

Constant (or continual) dry-weather flow - Uninterrupted flow in a storm sewer or drainage ditch occurring in the absence of rain. See baseflow.

Deposits and stains - Any type of coating or discoloration that remains at an outfall as result of dry-weather discharges.

Detection limit - A number of different detection limits have been defined: IDL (instrument detection limit), is the constituent concentration that produces a signal greater than five times the signal to noise ratio of the instrument; MDL (method detection limit) is the constituent concentration that, when processed through a complete method, produces a signal with a 99 percent probability that it is different from a blank; PQL (practical quantification limit) is the lowest constituent concentration achievable among laboratories within specified limits during routine laboratory operations. The ratios of these limits are approximately: IDL:MDL:PQL = 1:4:20 (APHA, et al. 1989).

Direct (dry-weather) entries into the storm drainage system - Sources which enter a storm drainage system directly, usually by direct piping connections between the wastewater conduit and the storm drain.

Domestic sanitary wastewater - Sewage derived principally from human sources.

Drainage area - The area of land from which a storm drainage system collects precipitation and storm runoff and then delivers the resulting stormwater to a specific point.

Dry-weather flow - Flow in a storm sewer or drainage ditch occurring in the absence of storm flow. But it is also a constituent of wet-weather flow. See baseflow.

Entries to storm drainage - Water (relatively clean or polluted) discharged into a stormwater drain from sources such as, but not limited to, direct industrial or sanitary wastewater connections, roof leaders, yard and area drains, cooling water connections, manhole covers, groundwater or subterraneous stormwater infiltration, etc.

Floatables - Floating materials, (plastic containers, condoms, sanitary napkins, tissues, corks, paper containers, wood, leaves, oil films, slimes, scum, etc.), that are either part of the inappropriate waste streams discharged to a stormwater system, or collected by flows which enter a stormwater drainage system.

Geographic Information System (GIS) - Computer software that maps land areas and produces images and information relating to the land area, e.g., topography, drainage, public utilities, roads, buildings, industry, land use, and demography.

Groundwater infiltration - Seepage of below water table groundwater and subterraneous stormwater into stormwater, sanitary wastewater, or combined sewer drainage systems, through such means as defective pipes, pipe joints, connections, or manhole walls.

Hardness - Caused by the presence of the divalent cations (principally calcium and magnesium) in water. Causes an increased amount of soap usage before producing a lather and scale to form in hot water pipes, boiler vessels, condensate return lines, cooling systems, kettles, etc.

House Lateral - A pipe connecting a house to a lateral or other sewerline. Also called a service connection.

Indirect dry-weather entries into the storm drainage system - Non-stormwater sources which enter a storm drainage system indirectly, usually by floor, areaway, and yard drains or inlets; and spills and dumping.

Industrial dry-weather entries into the storm drainage system - Any solid or liquid waste coming from industrial sources which enter storm drainage systems during periods of dry weather.

Infiltration - The process whereby water enters a drainage system underground through such means as defective pipes, pipe joints, connections, manhole walls, etc.

Inflow - The process whereby water enters a sanitary wastewater drainage system from surface locations, (e.g., through depressed manhole covers, yard and areaway inlets, roof leader setc.).

Intercepted stormwater/groundwater - The portion of surface runoff or groundwater moving through the soil that enters a storm drainage, combined sewer, or sanitary sewer system.

Interceptor - A sewer that receives flows from a number of wastewater trunk lines.

Intermittent dry-weather flow - Irregular flow in a storm drainage system occurring in the absence of storm flow.

Lateral - A drain or sewer that has no other drains or sewers discharging into it, except for service connections, or house laterals.

Leaching field - A system which facilitates the infiltration of a septic tank effluent into the soil. This is typically done by a pipe and infiltrating trench system which takes the effluent from a septic tank and distributes it through the leaching field, where additional treatment of the effluent occurs as it percolates through the ground or soil column.

Monte Carlo probabilistic simulation - A statistical modeling approach used to determine the expected frequency and magnitude of an output by running repetitive simulations using statistically selected inputs for the model parameters.

Municipal sewage/wastewater - Sewage/wastewater from a community which may be composed of domestic sewage/wastewater, industrial wastewater and/or commercial wastewater, together with subsurface infiltration.

National Pollution Discharge Elimination System (NPDES) - A national system of permits issued to industrial, commercial, and municipal dischargers to limit the amount of pollutants that can be discharged to waters of the USA.

Non-contact cooling water - Water that decreases the temperature of an object, without ever physically contacting the object.

Nonpoint pollution source- Any unconfined and nondiscrete conveyance from which pollutants are discharged, or an urban drainage system not under the NPDES. These sources are usually from agricultural, silvicultural, and rural land areas..

Outfall - In this User's Guide, an outfall refers to a point at which a stormwater drainage system discharges to a receiving water. There is sometimes a concrete structure or retaining wall at this location to protect the end of the discharge pipe and prevent erosion of the receiving water bank.

Pathogen - A disease-causing microorganism.

Point source - Any discernible, confined, and discrete conveyance from which pollutants are, or may be, discharged. Under the NPDES it is an outfall discharge, or overflow of treated or untreated sanitary, industrial, combined sewage, or stormwater (from a municipality greater than 100,000 in population).

Pollutant - Any material in water or wastewater interfering with designated beneficial uses.

Potable water - Water that has been treated, or is naturally fit for drinking, i.e., the water has no harmful contents to make it unsuitable for human consumption.

Precision - The measure of the degree of agreement among replicate analyses of a sample, usually expressed as the standard deviation.

Pretreatment - The removal of material such as, gross solids, grit, grease, metals, toxicants. etc. or treatment such as aeration, pH adjustment, etc. to improve the quality of a wastewater prior to discharge to a municipal wastewater system. This is usually done by the industrial user of the water, but can also refer to the initial treatment processes of a sewage treatment plant.

Process line discharge - The disposal of anything used in, or resulting from, a manufacturing process.

Process water - Water used in industry to perform a variety of functions, or as an actual product ingredient.

Receiving waters - Natural or man-made water systems into which stormwaters, or wastewaters, are discharged.

Rinse water - Water that cleans or reduces the temperature of an object through actual physical contact with the object.

Sanitary sewer - A sanitary wastewater drainage system intended to carry wastewaters from residences, commercial buildings, industrial plants, and institutions together with minor quantities of groundwater, stormwater and surface water that are not admitted intentionally [40 CFR 35.2005 (b) (37)].

Sanitary wastewater - Wastewater of human origin.

Service Connection - See house lateral

Septic tank - A tank which receives sanitary wastewater direct from its source, (usually residential), and permits settling of the heavy solids and floatation of greases and fats along with anaerobic digestion. Septic tanks, typically need to meet minimum regulatory standards, e.g., minimum volume and detention time.

Sewage - In this text the term "sewage" refers to sanitary wastewater or wastewaters generated from commercial or industrial operations, it does not include stormwater.

Sewer - A pipe, conduit or drain generally closed, but normally not flowing full, for carrying sanitary, industrial and commercial wastewater and storm-induced (combined wastewater and stormwater) flows.

Sewerage - System of piping and appurtenances, with and without control-treatment facilities for collecting and conveying wastewaters with or without pollution abatement from source to discharge.

Specific Conductivity - Expressed in microSiemens/cm (or micromhos/cm). It is an indication of the dissolved solids (charged) concentration in a liquid.

Storm drainage discharge - Flow from a storm drain that is discharged to a receiving water.

Storm drain - A pipe, or natural or man-made channel, or ditch, that is designed to carry only stormwater, surface runoff, street washwaters, and drainage from source to point of discharge [40 CFR 35.2005 (b) (47)].

Stormwater - Water resulting from precipitation which either infiltrates into the ground, impounds/puddles, and/or runs freely from the surface, or is captured by storm drainage, a combined sewer, and to a limited degree, by sanitary sewer facilities. See urban runoff and urban stormwater runoff.

Surfactants - Surface-active agents and common components in detergents which affect the surface tension of water and can cause foaming.

SIC - Standard Industrial Classification, a code used to describe an industry.

Total solids - The entire quantity of solids in the liquid flow or volume including the dissolved and particulate (suspended, floatable, and settleable) fractions.

Toxicity - The degree to which a pollutant causes physiological harm to the health of an organism.

Tracer - In this User's Guide, a tracer is a distinct component, or combination of components ("fingerprint"), of a polluting source which is identified in order to confirm the entry of the polluting source to a storm drainage system.

Trace Metals - Metals present in small concentrations. From a regulatory standpoint, this usually refers to metal concentrations that can cause toxicity at trace concentrations.

Turbidity - The lack of clarity in the water usually caused by suspended particulate matter and measured by interference to light penetration.

Urban runoff - Any runoff stormwater from an urban drainage area that reaches a receiving water body or subsurface. During dry weather, it may be comprised of many baseflow components, both relatively uncontaminated and contaminated. See stormwater and urban stormwater runoff.

Urban stormwater runoff - Stormwater from an urban drainage area that reaches a receiving water body or subsurface caused by weather precipitation (rain, snow, etc.). See stormwater and urban runoff.

Watershed - A geographic region (area of land) within which precipitation drains into a particular river, drainage system or body of water that has one specific delivery point.

Wet-weather flow - Any flow resulting from precipitation (rain, snow, etc.) which may introduce contaminants into storm drainage combined sewerage, or sanitary sewerage systems.

REFERENCES

Alhajjar, Bashar J., John M. Harkin, and Gordon Chesters. "Detergent Formula and Characteristics of Wastewater in Septic Tanks". Journal Water Pollution Control Federation, Volume 61, Number 5. May 1989.

APHA (American Public Health Association), American Water Works Association, and Water Pollution Control Federation. Standard Methods for the Examination of Water and Wastewater, 17th edition. American Public Health Association. Washington, D.C. 1989.

Beyer, D.L., P.A. Kingsbury, and J.E. Butts. History and Current Status of Water Quality and Aquatic Ecology Studies in the Lower Chehalis River and Grays Harbor, Washington. Prepared for Washington Public Power Supply System. 1979.

Cochran, William G. Sampling Techniques. Second edition. John Wiley and Sons, Inc. New York. 1963.

Evans, R.L. "Addition of Common Ions from Domestic Use of Water." Journal American Water Works Assn. Volume 60, No.3. p 315. 1968.

EPA (U.S. Environmental Protection Agency). Results of the Nationwide Urban Runoff Program, Water Planning Division, NTIS number PB 84-185552, Washington, D.C., December 1983.

Falkenbury, John. Water Quality Standard Operating Procedures. City of Fort Worth Public Health Department, 1800 University Drive, Fort Worth, Texas 76107. 1987.

Falkenbury, John. City Of Fort Worth Water Pollution Control Program Overview. Fort Worth Public Health Department, 1800 University Drive, Fort Worth, Texas 76107. 1988.

GLA (Gartner Lee and Associates, Ltd.). Toronto Area Watershed Management Strategy Study, Technical Report #1, Humber River and Tributary Dry-weather Outfall Study. Ontario Ministry of the Environment. Toronto, Ontario, November 1983.

Hypes, W.D., C.E. Batten, J.R. Wilkins. Processing of Combined Domestic Bath and Laundry Waste Waters for Reuse as Commode Flushing Water. Technical Report NASA TN D-7937. National Aeronautics and Space Administration. October, 1975.

Montoya, Barry L. Urban Runoff Discharges From Sacramento, California. Prepared for the California Regional Water Quality Control Board, Central Valley Region, CVRWQCB Report Number 87-1SPSS. 1987.

Moore, A.H. and Dena Hoffpauir. Biotoxicity Testing. Fort Worth Health Department, 1800 University Drive, Fort Worth, Texas 76107. 1988.

Murray, James E., Washtenaw County Drain Commissioner. Statement To The Board Of Commissioners. December 1985.

Pelletier, G.J. and T.A. Determan. Urban Storm Drain Inventory Inner Gray Harbor. Prepared for Washington State Department of Ecology, Water Quality Investigations Section, Olympia, Washington. 1988.

Pitt, Robert and Melinda Lalor. Birmingham, Alabama, Draft Final Report: Demonstration Project for the Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems. U.S. Environmental Protection Agency. Storm and Combined Sewer Pollution Control Program. Edison, New Jersey. Contract No: 68-C9-0033. Publication pending.

Pitt, Robert and James McLean. Toronto Area Watershed Management Strategy Study; Humber River Pilot Watershed Project. Final Report. The Ontario Ministry Of The Environment. Toronto, Ontario. 1986.

Schmidt, Stacy D. and Douglas R. Spencer. "The Magnitude of Improper Waste Discharges in an Urban Stormwater System", Journal Water Pollution Control Federation, Volume 58, Number 7. July 1986.

van der Leeden, Frits, Fred L. Troise and David Keith Todd. The Water Encyclopedia. Lewis Publishers. Chelsea, Michigan. 1990.

Verbanck, Michel, Jean-Pierre Vanderborght, Roland Wollast. "Major Ion Content of Urban Wastewater: Assessment of Per Capita Loading." Journal Water Pollution Control Federation. Volume 62, Number 1. January, 1990.

Washtenaw County Drain Commissioner and Washtenaw County Health Department. Allen Creek Drain Water Quality Survey - Status Report. September 1984.

Washtenaw County Statutory Drainage Board. Huron River Pollution Abatement Program. September 1987.

Washtenaw County Drain Commissioner. Huron River Pollution Abatement Project, Summary. 1988.

Washtenaw County Statutory Drainage Board. Huron River Pollution Abatement Program. September 1987.

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